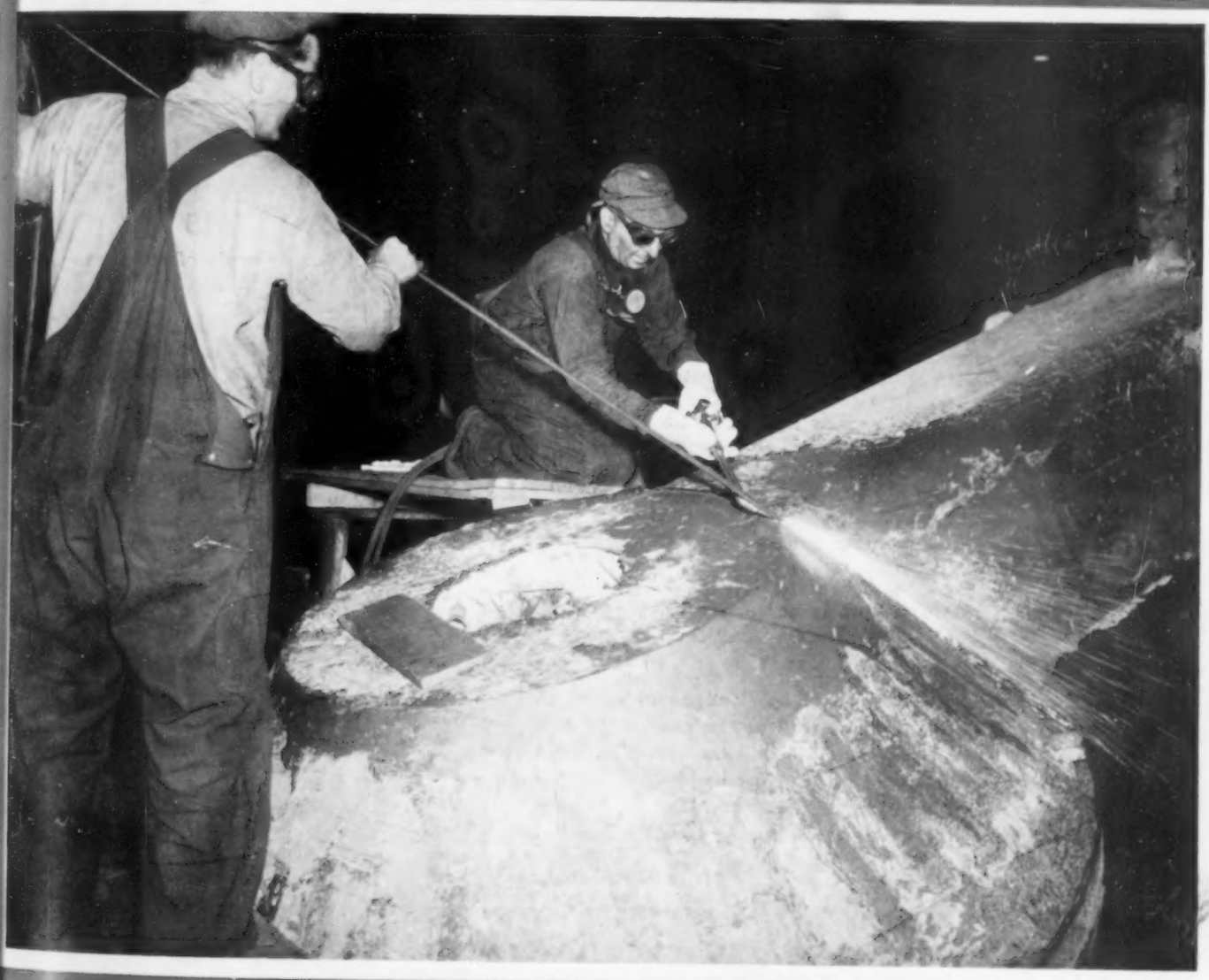
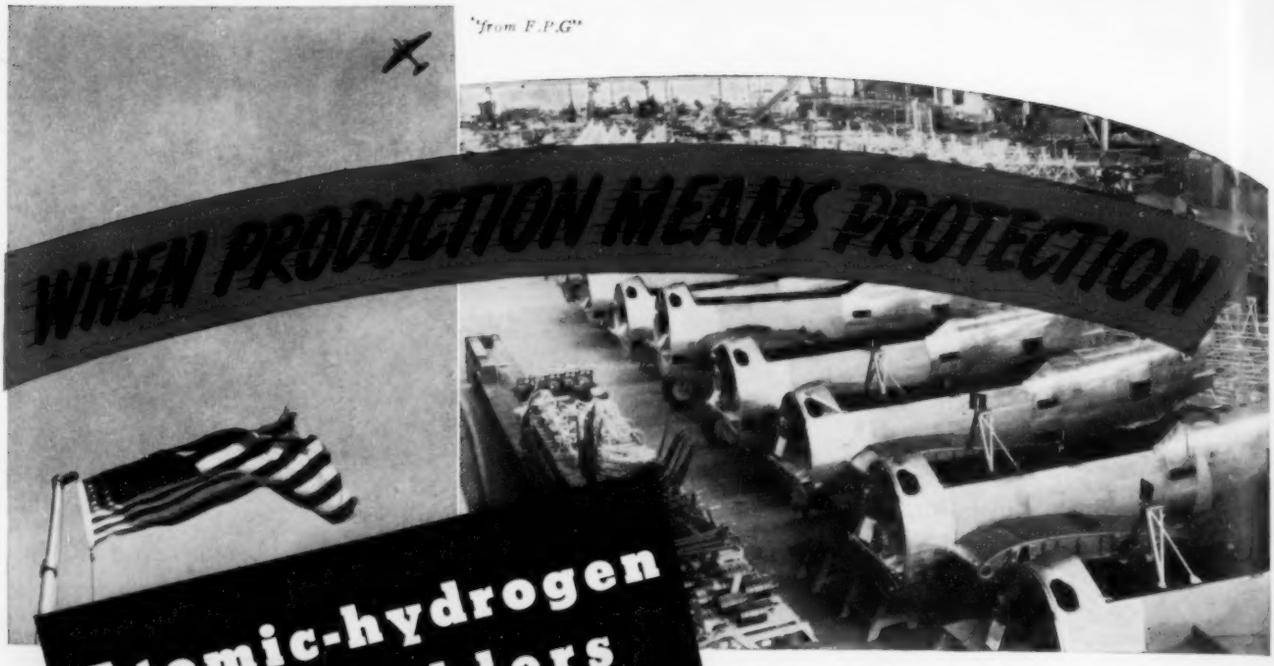
NOVEMBER 1940

# The WELDING Journal



The Journal of the American Welding Society

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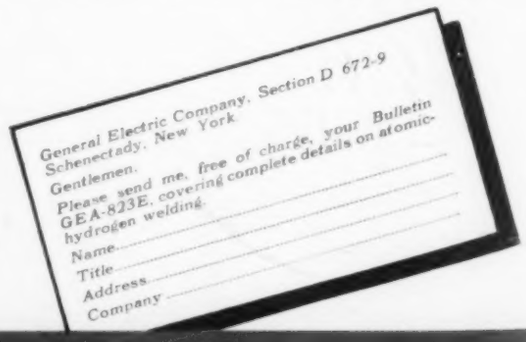
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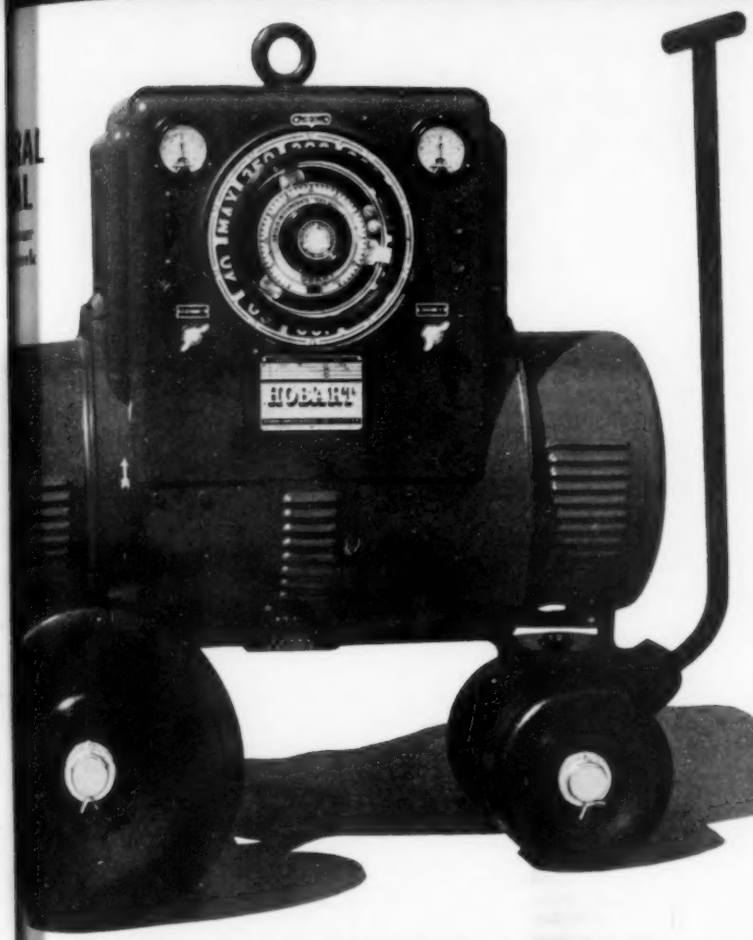


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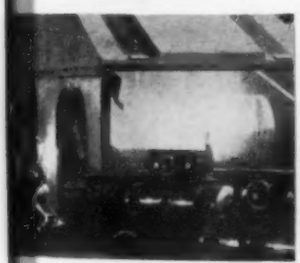

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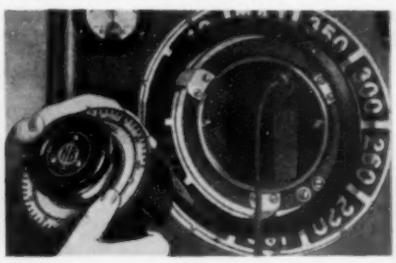

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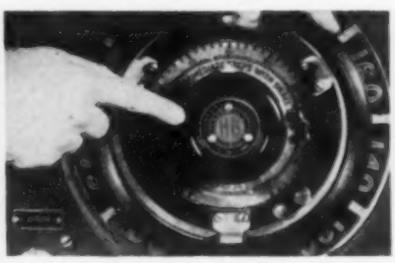

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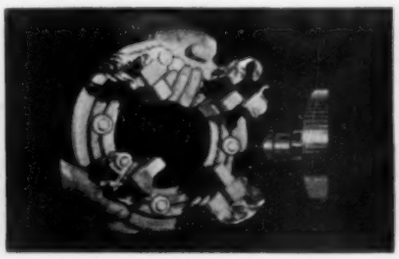

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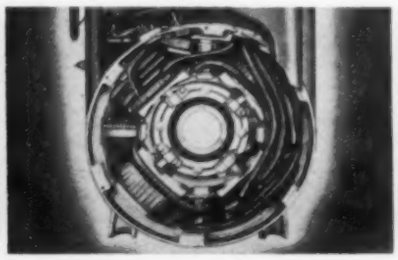

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# The American Welding Society Journal

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**COVER**

Cutting Risers with Oxygen Lance Assisted by Oxyacetylene Blowpipe.

*Photo, Courtesy The Linde Air Products Company*

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Welding Journal

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# WELDING IN SHIPBUILDING*

By DAVID ARNOTT†

THE development of ship construction provides a very interesting study. In the wood ship era Naval Architecture was an art rather than a science and there were definite limitations to the use of wood as a material of construction even when sound and properly seasoned timber in long lengths was readily available. It was impossible to work in sufficient fastenings to develop the full strength of the material and a proper shift of butts, i.e., keeping the plank ends well clear of one another, was essential for structural efficiency. Under stress of weather in heavy seas the wood ship creaked and groaned and its constituent parts tended to move relatively to one another and to force out the oakum from the caulked seams necessitating periodic recaulking to keep the ship even reasonably tight. In time, the ends

* Presented at the Annual Meeting, A. W. S., Cleveland, Ohio, Oct. 21 to 25, 1940.

† Vice-President and Chief Surveyor, American Bureau of Shipping, New York, N. Y.

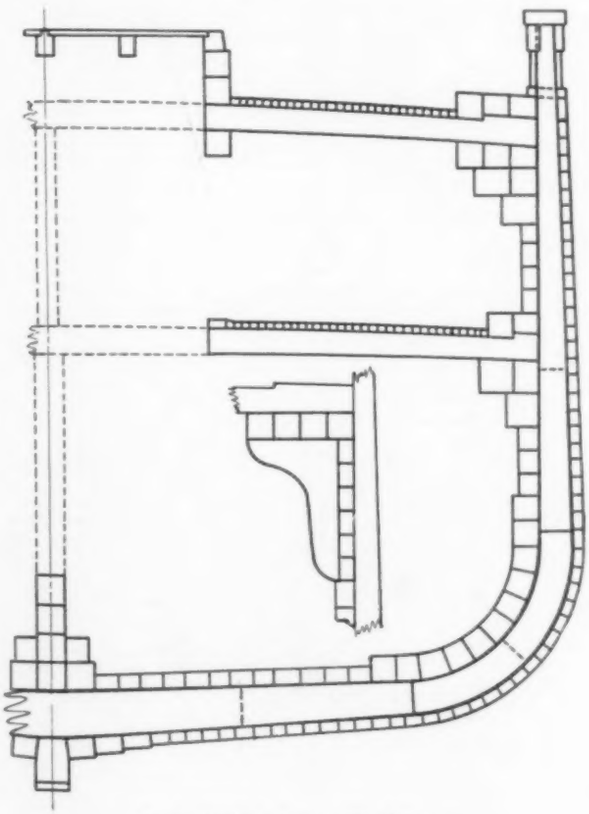

Fig. 1—Midship Section Wood Steamer

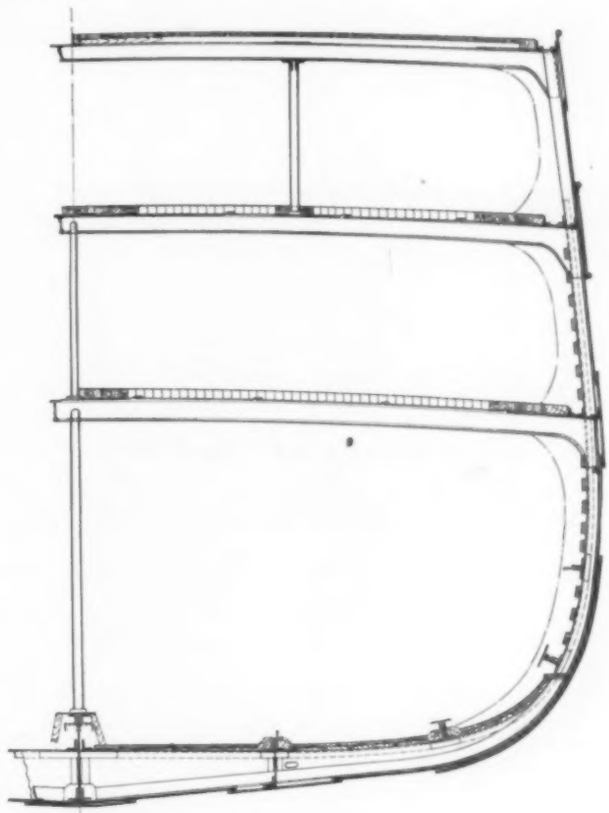

Fig. 2—Midship Section Coastwise Steamer Hurricane Deck Type

of the ship tended to droop as also the bilges. In shipbuilding parlance, the vessels hogged considerably, a hog of three or four feet in old wood ships after a period of service being not unusual. Under such conditions it was no wonder that the largest wood ships built were around 300 feet in length with easy proportions of length to depth, an $L/D$ ratio of about 10. Applying scientific principles to the analysis of the structural strength of these old wood ships one is forced to conclude that relatively too much material was piled in the bottom structure, presumably in support of the fetish that the keel was "the backbone of the ship" and too little material on the deck which constitutes the top flange of the hull girder. However, one has got to hand it to these early builders of wood ships who by rule-of-thumb methods based on experience and the exercise of considerable resource and ingenuity were able to build sea-

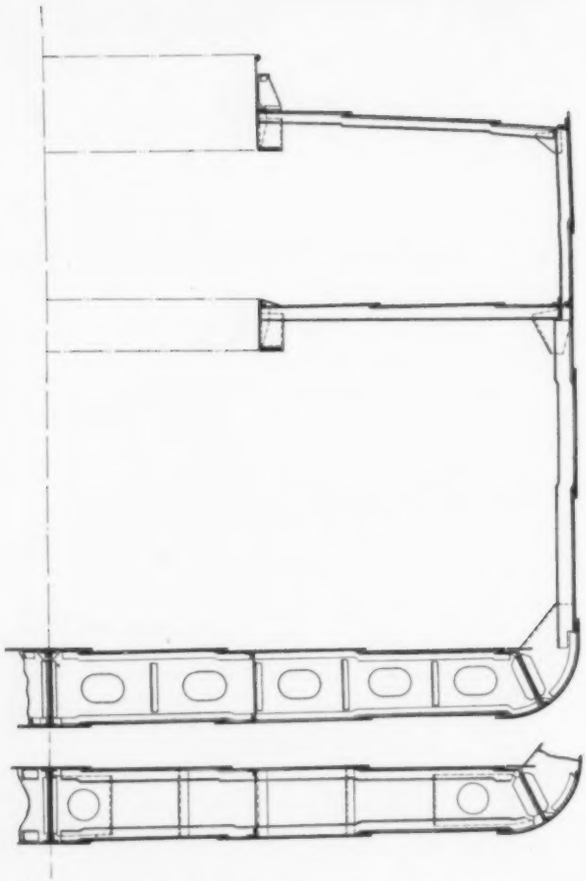

Fig. 3—Midship Section Modern Riveted Cargo Ship

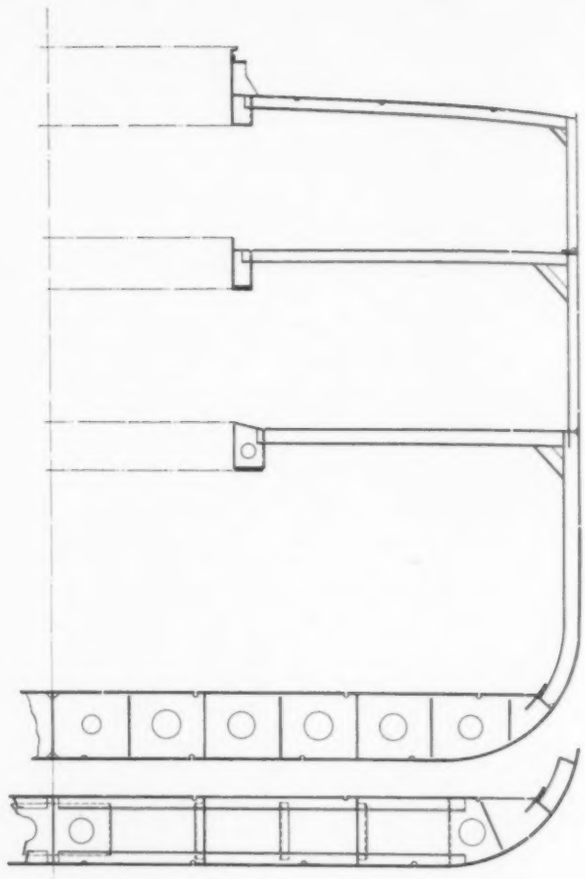

Fig. 4—Midship Section Modern Welded Cargo Ship

worthy ships out of the material of construction then available.

Figure 1 shows a midship section of a Ferris type wood steamer of which so many were built during the World War. These ships passed out of the picture very quickly after emergency was over as they were uneconomical in operation and could not compete with the steel ship. It is impossible to show in the diagram the nature and extent of the numerous fastenings holding the various timbers together such as through bolts, edge bolts, treenails and spikes.

When iron ships came to be built it was almost inevitable and certainly human that some of the practices inherent to wood ship design should be continued and the fullest advantage of the infinitely superior material from a structural strength point of view was not taken for many years to come. Too much emphasis was still placed on the bottom structure as was evidenced by the number of heavy keelsons usually fitted. Continuity of such structural members as keelsons and side stringers through watertight bulkheads was considered essential and necessitated the fitting of numerous and costly smith-welded watertight angle collars and staples. Obtainable iron plates were comparatively narrow and short, resulting in large numbers of seams and butts with plenty of riveting. A bar keel was a common feature of these iron ships and the various parts of the ship's structure including the bulkheads were assembled piece by piece and plate by plate on the ways. The *Great Eastern* about 680 feet long, built in 1858, a Leviathan for those days, was away ahead of her time and an outstanding example of what could be done with wrought iron as a material of construction, in the hands of her designer, Mr. Brunel, who had little regard for precedent but did have a practical knowledge of the mechanics of structures.

When mild steel came into use for shipbuilding about 60 years ago its superiority for structural purposes was recognized by the Classification Societies allowing a 20 per cent reduction from the scantlings required for iron ships. The scantlings for iron ships were tabulated in sixteenths of an inch and this meant in effect that an iron shell plate required to be, say, $^{5}/_{16}$ in thickness was accepted at $^{5}/_{20}$ if of steel.

A midship section of a coastwise steamer of the hurricane deck type built about 1900 is shown in Fig. 2. In this type of vessel the bulk of the cargo is loaded through side ports and not through hatches on the deck. This is a single bottom ship, no double bottom being fitted for the carriage of water ballast or fuel oil as is now common practice and required by law as a safety measure in the case of the larger passenger ships. Note the cumbersome side stringers which were comparatively ineffective unless fitted in association with closely spaced web frames. The second deck is the strength or main deck as against the modern practice of considering the top or superstructure deck as the upper flange of the hull girder and making it the heavy or strength deck. The hold framing consists of a frame and reverse angle, the beams on all decks are bulb tees fitted on alternate frames with a pillar on every beam. The forge-welded beam knees are interesting and were the forerunner of plate bracket connections.

The beginning of the steel ship era was coincident with the general application of scientific principles to ship structural design. Since then the trend in merchant ship construction has been toward simplicity of design and

greater economy of material through the gradual elimination of parts which were more or less redundant and by reductions in scantlings made possible by a more effective distribution of material.

American shipbuilders ever on the lookout for cutting costs without sacrifice of efficiency were quick to take advantage of pneumatic riveting and gradually got away from the piecemeal method of assembly by improved production methods involving increased mold loft work, plate templates being made in the loft rather than lifted from the ship and by assembling such items as bulkheads on the ground or in the shops rather than on the building ways. In recent years the practice has been to sub-punch and ream and even in some cases to drill the holes in shell plating with a view to improving the quality of the riveting as it is usually the riveting and caulking that gives trouble in service, the renewal of leaky or corroded rivets being a source of considerable expense to an owner throughout the life of the ship.

A midship section of a modern riveted cargo ship is shown in Fig. 3 and a comparison with Fig. 2 will show the trend of development in ship structural design. The frames and beams are channels joggled in order to eliminate the necessity of fitting liners in way of outside strakes of plating. Wide-spaced pillars are fitted at the center line in association with deck girders and no side stringers are fitted. In the double bottom solid floors are fitted on every third frame, the intermediate open floors providing easy access for tank examination and cleaning. Relatively wide shell plates are used in order to cut down the amount of riveting. As compared with Fig. 2 the relatively clear space provided for cargo in order to minimize broken stowage is apparent. With maximum joint efficiencies for riveted end connections in the order of about 75 per cent, good design still requires an effective shift of butts in the strakes of plating especially of the shell and strength deck.

It is a fact that prior to the general use of arc welding we had reached such a high degree of efficiency in the design and construction of riveted ships as a result of the application of scientific principles to their design and of the experience gained through close observation of ships under service conditions that it was becoming increasingly difficult to conceive how any further major reductions in scantlings or improvements in structural design

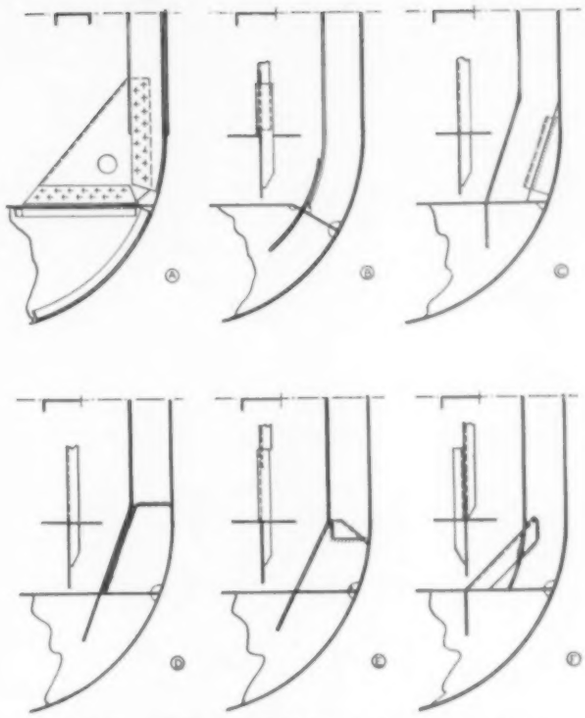


Fig. 5—Various Types of Hold Frame Margin Connections

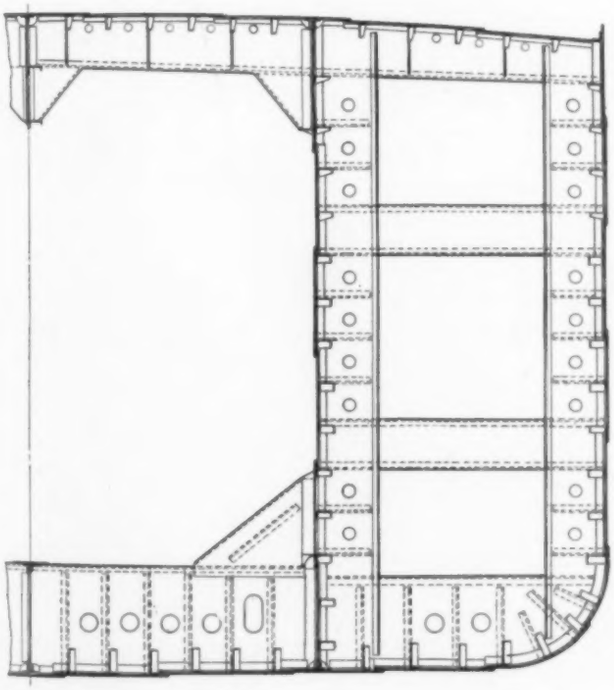

Fig. 6—Midship Section of Riveted Tanker

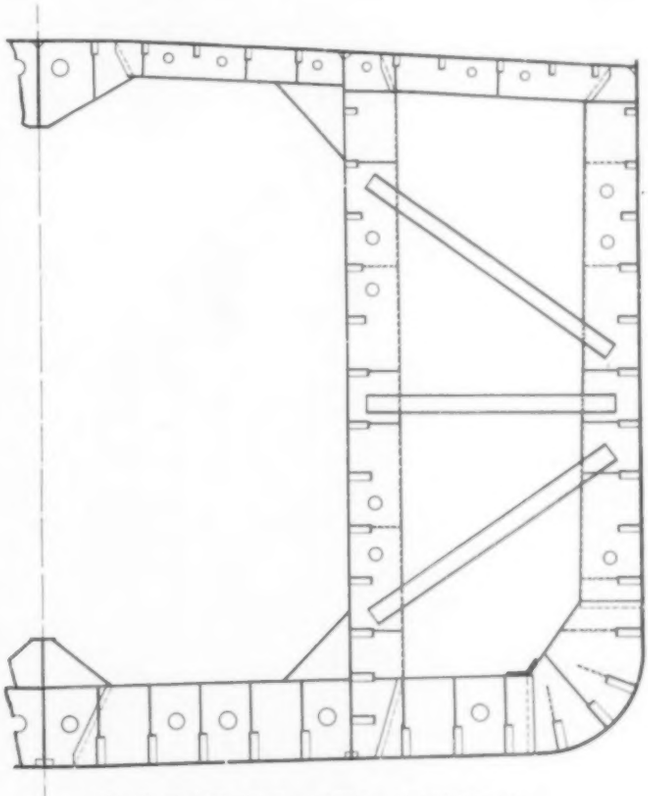

Fig. 7—Midship Section of Modern Welded Tanker

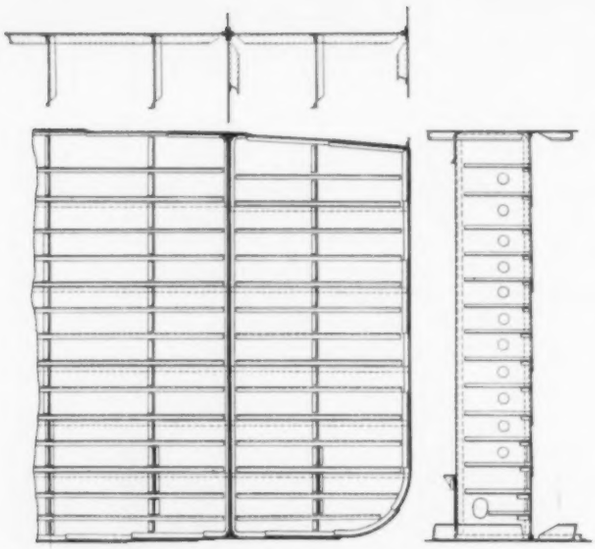

Fig. 8—Typical Riveted Tanker Bulkhead

could properly be effected without the general adoption of special and more expensive steels.

The application of welding to ship construction has opened up an entirely new vista providing as it does a new tool for the production of more efficient and more economical hull structures. The earlier welded ships were, as one would expect, merely riveted designs welded so that economy from the use of the new process was not at first achieved. The midship section of a modern welded cargo ship illustrated in Fig. 4 shows considerable progress over such early designs. The saving in weight of hull material from the riveted ship in Fig. 3 is obvious and largely due to the elimination of faying flanges, plate laps, etc. The frames and beams are inverted angles cut from channels. In this particular design the second and third deck beams; also the reverse bars on open floors, were serrated and cut from channels. The beam connections to frames are angles instead of ordinary plate knees. This midship section is fairly typical of the welded cargo ships being built today although there are many differences in detail in the ships now under construction which cannot be described within the scope of this paper.

Various types of hold frame margin connections in association with a flat tank top are shown in Fig. 5. *A* shows the usual riveted plate bracket connected with tee bars to the tank top and with reverse bar and back bar directly underneath. *B* is a detail of a welded type of connection used in the vessel shown in Fig. 4, where the hold frame is cut at and welded to the knuckled margin plate and reinforced by a flat bar gusset welded to the frame flange and to the floor plate and fitted continuously through the slotted margin plate. In detail *C* the hold frame is knuckled, the gap between the back of the frame and the shell being filled in by a welded plate. In detail *D* the cutting of the web of the frame near the frame flange facilitates the forming of the knuckle. The type shown in *E* is intended to eliminate bending of the main hold frames in the midship body; the bracket between the main frame and the tank top was cut from an 18-inch channel. In detail *F* the angle gusset is in some cases butted to the main frame and not lapped as shown in the sketch. It should be emphasized that these details are not intended to be directly comparable as far as size of hold frame, etc., is concerned. They do, however, serve to show the differences of opinion with regard to what constitutes an effective and economical welded hold frame connection. Such diversification is inevitable and even desirable during the present transition stage from riveted to welded construction.

Figure 6 is a midship section of a riveted tanker on the longitudinal system of framing, a modern twin bulkhead type, i.e., with two longitudinal bulkheads and three oil tanks abreast. The shell and deck longitudinals are channels and bulb angles. It is interesting to note the large number of angle clip attachments, in most cases double riveted incidental to riveted construction.

Figure 7 shows a midship section of a modern welded tanker. This looks like a simple structure compared with Fig. 5 due to the absence of clip attachments, plate laps, etc. The longitudinals are of the inverted angle type, the smaller sizes being rolled angles and the larger sizes formed from flanged plates. The various preassembly units are indicated on the section by the laps of the deck, side and bottom transverses.

Figure 8 shows a typical riveted tanker bulkhead

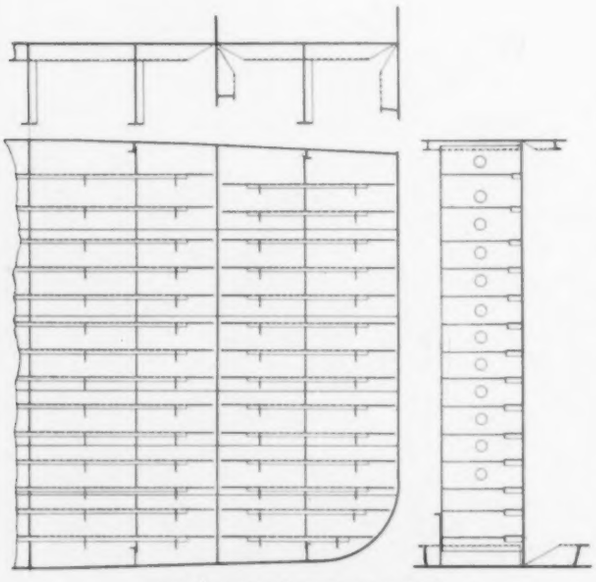

Fig. 9—Welded Tanker Bulkhead

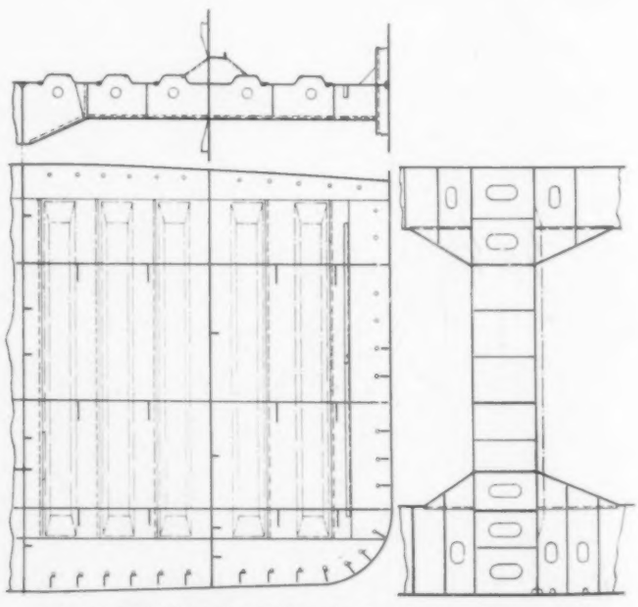

Fig. 10—Welded Tanker Bulkhead—Frear System of Construction

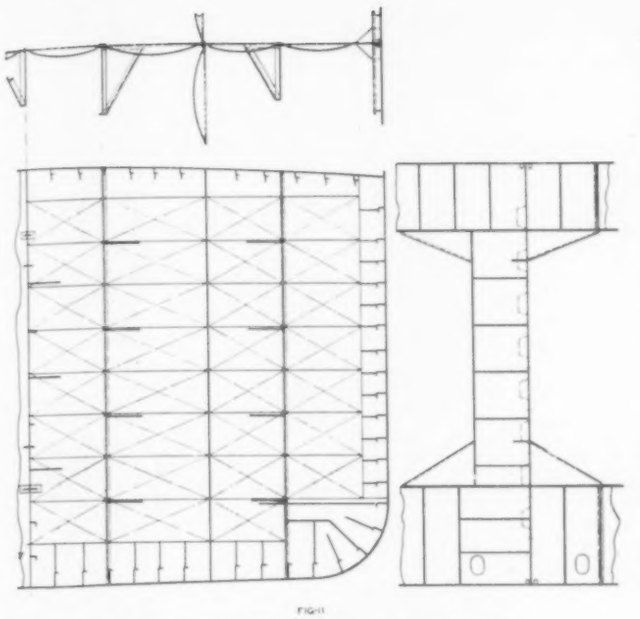

Fig. 11—Welded Bulkhead with Dished Plates

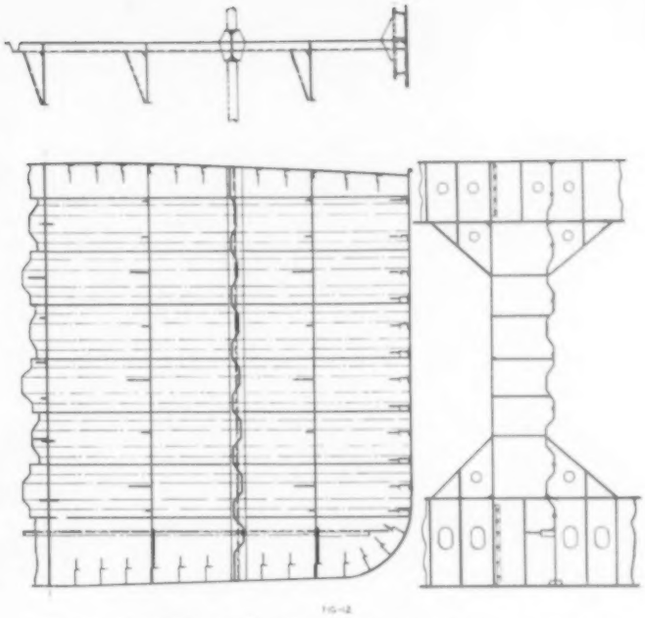

Fig. 12—Welded Tanker Bulkhead—Isherwood Corrugated System

stiffened by large vertical webs and horizontal channel stiffeners. It will be noted that the bulkhead double boundary bars are fitted in short lengths and butt welded in lieu of joggling.

Figure 9 is a somewhat similar bulkhead to that shown on Fig. 8 except that it is welded instead of riveted. The horizontal stiffeners at the top of the bulkhead are inverted rolled angles, flanged plates being used at the bottom of the bulkhead as rolled angles of these dimensions are not commercially obtainable.

Figure 10 shows a welded tanker bulkhead built on the Bethlehem-Frear system of construction. The main stiffening members are the center vertical web and the two horizontal girders, the vertical fluted plates taking the place of the usual secondary stiffeners. These flutted plates are pressed into shape hot and joined by continuous lap welds.

Figure 11 shows another type of welded bulkhead for a tanker where the bulkhead plates were dished to the form shown, at the plant of the Lukens Steel Company.

Figure 12 shows still another special application, a tanker welded bulkhead built on the Isherwood corrugated system, where the shaped plates of varying depths of corrugation are butted at the edges instead of being lapped.

Figure 13 shows various types of connections of longitudinals to oiltight bulkheads which provide a desirable degree of continuity for the longitudinals which are necessarily cut at the transverse bulkheads in order to provide for proper drainage. *A* and *B* are details of the Frear bulkhead shown in Fig. 10. *C* is a detail of the continuous bracket plate connection used in the bulkheads shown in Fig. 11 and Fig. 12. It is obvious that these particular details are only applicable to welded construction.

In the year 1934 I presented a paper to the Society of Naval Architects and Marine Engineers entitled "Some Examples of Arc Welded Ship Construction," outlining the development of ship welding up to that time. It is always interesting to go back and see what one has said on some specific subject and a review of that particular paper emphasizes the tremendous development that has taken place in the application of welding to ship construction in this country during the past six years. It is only some 12 years ago since the plans were approved for the first all-welded piece of floating equipment to be built under American Bureau classification, a small propelled oil barge *Supertest* ex *Pioneer* 102 x 20 x 8 feet which by the way was welded throughout with bare wire. The largest all-welded ship described in the paper was the tanker *Poughkeepsie Socony* 252 x 40 x 14 feet completed in 1934 and designed for Great Lakes, Canal & Short Coastwise Service.

Tanker owners were the first to grasp the significance of welded construction, the advantages being readily apparent in the case of oil-carrying vessels such as saving the hull material of the order of 15 to 20 per cent with consequent increased deadweight, superior oiltightness, easier cleaning of tanks and cheaper repairs. The Atlantic Refining Company on the basis of their satis-

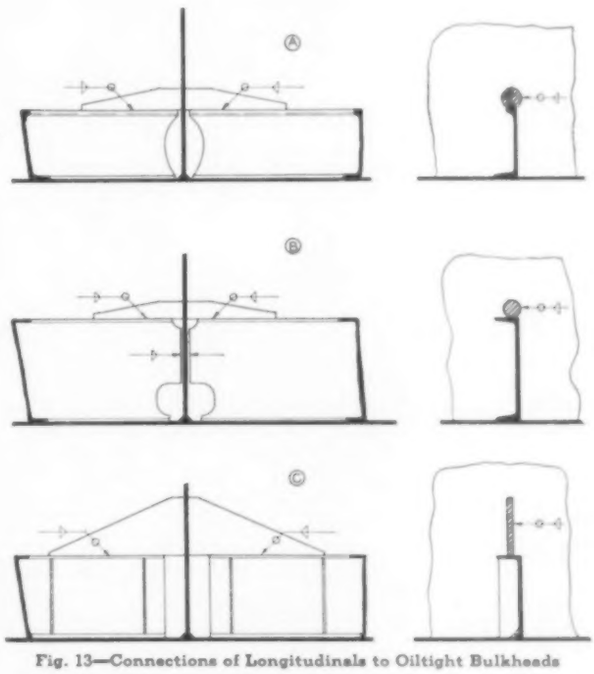


Fig. 13—Connections of Longitudinals to Oiltight Bulkheads

COMPARATIVE APPLICATION OF RIVETING AND WELDING IN LARGE MERCHANT VESSELS
UNDER CONSTRUCTION OR CONTRACTED FOR, ON SEPTEMBER 1 1940,
TO A. B. S. CLASS, IN UNITED STATES SHIPYARDS.

| BUILDER | LENGTH | TYPE | NUMBER OF VESSELS | SHELL | | WEATHER DECK | | | LOWER DECKS | | | BULKHEADS | | | | FRMS | | FLOORS | | T.T. PL.TG. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SEAMS | BUTTS | SEAMS | BUTTS | BEAMS-LONGITUDINALS | SEAMS | BUTTS | BEAMS-LONGITUDINALS | SEAMS | BUTTS | STIFFENERS | BOUNDARY | TO SHELL BOTTOM | TO SIDE SHELL | TO SHELL | TO TANKTOP | SEAMS | BUTTS |
| BATH IRON WORKS CORP. | 400 | CARGO - C | 4 | R | W | R | W | W | W | W | W | W | W | W | R | W | R | W | W | W | W |
| BETH. STEEL CO. QUINCY, MASS. | 450 | C | 3 | R | W | R | R | R | R | W | R | R | W | W | R | R | R | R | R | R | W |
| DO. | 487 | TANKER-T | 3 | R/W | W | R | W | R | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 450 | T | 4 | R/W | W | R | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 505 | T | 2 | R/W | W | R | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| BETH. STEEL CO. SPARROWS PT., MD. | 525 | T | 1 | R | W | R | W | R | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 465 | C | 4 | R | R | W | W | R | W | W | W | W | W | W | R | R | R | R | R | R | R |
| DO. | 450 | C | 6 | R | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 395 | C | 5 | R | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 487 | T | 8 | R/W | W | R | W | R | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 442 | T | 5 | R | R | R | R | R | R | W | W | W | W | W | W | W | R | W | W | W | W |
| BETH. STEEL CO. SAN FRAN., CAL. | 395 | C | 5 | R | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| BETH. STEEL CO. S.I., N.Y. | 395 | C | 5 | R | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| CARGILL INC. | 400 | C | 1 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| CONSOLIDATED STEEL CORP. LTD. | 395 | C | 4 | R | W | W | W | W | W | W | W | W | W | W | W | R | R | R | W | W | W |
| FEDERAL S. B. & D.D. CO. | 465 | C | 4 | R | R/W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| DO. | 395 | C | 5 | R | W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| DO. | 435 | C | 8 | R | W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| DO. | 440 | T | 1 | R | R | R | R | R | R | W | R | W | W | W | W | R | R | W | W | W | W |
| DO. | 505 | T | 4 | R | W | R | W | R | W | W | W | W | W | W | W | W | R | W | W | W | W |
| INGALLS S.B. CORP. | 465 | C | 8 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 465 | C | 7 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| MANITOWOC S.B. CO. | 386 | C | 1 | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R | R |
| MOORE D.D. CO. | 465 | C | 3 | R | R | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| NEWPORT NEWS S.B. & D.D. CO. | 525 | T | 1 | R | W | R | W | R | R | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 465 | C | 7 | R | W | R | W | R | R | W | R | W | W | W | W | R | R | R | W | R | W |
| DO. | 465 | C | 2 | R | W | R | W | R | R | W | R | W | W | W | W | R | R | R | W | R | W |
| DO. | 435 | C | 1 | R | W | R | W | W | R | W | W | W | W | W | W | R | R | R | W | R | W |
| PENNSYLVANIA SHIPYARDS INC. | 390 | C | 2 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| PUSEY & JONES CO. | 390 | C | 2 | R | W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| SEATTLE TACOMA S.B. CORP. | 395 | C | 5 | W | W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| DO. | 465 | C | 4 | W | W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| SUN S.B. & D.D. CO. | 465 | C | 4 | R | W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| DO. | 375 | T | 1 | R | W | R | W | R | W | W | R | W | W | W | W | W | R | W | W | W | W |
| DO. | 521 | T | 13 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 485 | T | 4 | R | W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| DO. | 450 | C | 8 | R | W | W | W | W | W | W | W | W | W | W | W | W | R | W | W | W | W |
| DO. | 500 | T | 5 | R | W | R | W | R | W | W | W | W | W | W | W | W | R | W | W | W | W |
| TAMPA S.B. & ENG. CO. | 435 | C | 7 | R | W | R | W | R | W | W | W | W | W | W | W | R | R | R | R | R | W |
| WELDING SHIPYARDS INC. | 500 | T | 1 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| WESTERN PIPE & STEEL CO. | 395 | C | 5 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| DO. | 465 | C | 4 | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W | W |
| | | | | | | | | | | | | | | | | | | | | | |

R/W - INDICATES RIVETED SIDE & WELDED BOTTOM

factory experience in service of their small all-welded tankers *White Flash* and *Franklin* built by the Sun Shipbuilding Company in 1931 and 1934, respectively, undoubtedly gave a boost to ship welding when they ordered the large tanker *J. W. Van Dyke* from the same builders. In this tanker, also the ships *Pennsylvania Sun* and *Robert H. Colley* which were delivered in 1938, all the middle bodies comprising the cargo oil tanks were completely welded, only the ends being riveted and I understand that these vessels have given every satisfaction in service. The later tankers of the same dimensions and type, the *E. J. Henry* and *Robert C. Tuttle*, were completely welded as will also be 13 similar tankers now under contract for various owners at the plant of the Sun Shipbuilding Company. This company was the first shipyard to apply the Unionmelt Process of automatic welding which is now being used quite extensively and so successfully in ship welding in this country.

In the last few years the use of ship welding has accelerated to such an extent that we are rapidly approaching that stage of development where welding will become the normal method of joining together the various parts of the ship's structure. This is borne out by the fact that all of the 149 ships under 300 feet long, building or contracted for to American Bureau class on September 1, 1940, and comprising barges, ferryboats, towboats, small tankers, etc., are to be completely welded. There are also 177 ships over 300 feet long now building to Bureau class of which no fewer than 41 will be all-welded including such large ships as the 13 521-feet tankers building by the Sun Shipbuilding Company, the 15 465-feet C-3 type Maritime Commission cargo vessels under contract at the Pascagoula plant of the Ingalls Shipbuilding Corporation, the two 390-feet Maritime Commission C-1 type cargo ships building by the Pennsylvania Shipbuilding Company at Beaumont, Texas, and the 9 vessels for the Maritime Commission building by the Western Pipe and Steel Company at San Francisco. Of the 136 remaining large vessels, 135 are part welded including practically the whole internal structure and in some cases only the shell and strength deck longitudinal seams are riveted. Only one vessel, a large carferry building on the Great Lakes, can be properly termed a riveted vessel although even in this particular case a certain amount of welding is being done. These are remarkable figures which reflect the increasing confidence in the structural efficiency of welded ships and the realization on the part of our shipowners of the many advantages to be gained by the new method of construction.

In order to amplify the foregoing résumé a table has been prepared to show the comparative application of riveting and welding in the principal parts of the larger merchant ships now under construction in U. S. shipyards. A study of the information given in the table only goes to show that in most cases part riveted rather than part welded would more aptly describe those ships that are not completely welded. For example, in the case of the ships building by the Seattle-Tacoma S. B. Corporation only the frames to the side shell are riveted. It will be noted also that the particular shipyards which are building completely welded vessels exclusively are, as would be expected, our new shipyards. The older yards still have their equipment for riveting, also a staff of trained riveters whom they naturally desire to keep in employment if at all possible. Owners' representatives have also something to say in the question of whether to rivet or weld, although in the case of the vessels ordered by the Maritime Commission the builders were given a free hand in the matter.

When welding was first introduced in our shipyards some 25 years ago bare wire electrodes were used exclusively and the work was usually left to some handy man without any special training or experience. While the use of welding in those early days was confined to repairs and to comparatively unimportant structural details the results did not always inspire confidence so that considerable prejudice and antipathy on the part of shipyard executives and owners' superintendents had to be overcome before welding came into its own. Bare wire versus covered electrodes is no longer an issue as bare wire welding is as dead as a "dodo" so far as modern shipyard practice is concerned. The work of the Navy Department in setting up standards for ship welding, testing of welders and welding procedures for navy ships with a view to the utmost possible saving in weight, an essential feature of navy design, and the early encouragement and approval given by the American Bureau of Shipping for welding important structural members in merchant ships undoubtedly served to encourage the development of welding in our shipyards. The activities of the AMERICAN WELDING SOCIETY, its publications and research work, have been stimulating and entirely helpful in assuring builders and owners that welding can be made safe and sound.

Advantages of welded construction to the shipowner such as increased deadweight capacity and lower maintenance costs are becoming generally recognized but what about initial construction costs? So far as barges are concerned especially those of rectangular section and rake ends of which so many are built on our rivers, usually in lots of 10 to 30, it can be stated quite definitely that there is a decided saving in initial cost as compared with riveted barges of the same type and our river yards are now building welded barges exclusively. The barge building business is highly competitive and it is significant that such important river yards as the Dravo Corporation and the Leetsdale plant of the Bethlehem Steel Company are now laid out for welding and quantity production, the Dravo plant, for example, being equipped for a line assembly of barges, the bulk of the welding being done under cover. At the Leetsdale plant the automatic carbon arc process is used quite extensively and a considerable use is made of jigs and fixtures to the exclusion of mold loft work.

The comparative costs of riveting and welding so far as the large oceangoing ships are concerned are somewhat more elusive, depending on the facilities of the particular yard, such as available storage and assembly spaces, crane capacities, welding equipment, method and sequence of preparing sub-assemblies, etc. Costs can be cut by careful planning in the initial stages of the design to ensure that only the minimum amount of welding is specified and so arranged that the maximum amount of welding can be done in the down-hand position. The advantage of using large plates to cut down the number of joints is, of course, obvious always with due regard to the extras charged for plates over certain sizes and to weight tolerances. Mr. E. C. Rechtin of the Bethlehem Steel Corporation in an address to the New York Section of the AMERICAN WELDING SOCIETY, published in the April issue of the Journal, discussing the economics of ship welding had no hesitation in affirming "that properly designed welded ships constructed in a properly laid-out yard are not more expensive to build than riveted ships" and went on to say "that the cost of a riveted ship expressed in man hours per ton was not likely to get any less as time goes on while the whole trend of development in ship welding is in the direction of reducing costs." It seems safe to say that so far as this country is concerned cost is no longer an important factor in the choice between riveting and welding.

The welded ships built in our shipyards have so far been free from serious structural troubles in service but it is entirely too early to jump to the conclusion that troubles will be non-existent as it will take years of operation under the varied service conditions before we can claim definite superiority for the welded ship structure. Welding is now being commonly used in the construction of the larger oceangoing type vessels where the service stresses are relatively much higher than in the smaller ships and for these important and complicated structures the best welding is none too good if trouble is to be avoided throughout the useful service life of the ship which is usually assumed to be around 20 to 25 years. Oceangoing ship structures especially tankers are subject to considerable corrosion depending on the degree of maintenance and since welding can make no difference in this respect the desirable margins provided for wear and tear in riveted ships must necessarily be retained.

The ideal of a perfectly homogeneous structure where the base metal and the weld metal have exactly the same characteristics and properties is not obtainable. A fusion weld is essentially a casting having comparatively low ductility and the fatigue strength of deposited weld metal is definitely lower than that of mild steel. Welds should, as far as practicable, be free from porosity, inclusions and insipient cracks all of which act as stress raisers. Lack of penetration and undercutting are obvious defects which may impair the efficiency of the joint to the extent of becoming dangerous and the aim should be to produce welded joints with the maximum degree of reliability. Fortunately, we have in ordinary commercial mild steel a material which is inherently suitable for welding. Any steel can be satisfactorily welded using special welding technique in association with preheating or so-called stress relieving but what shipbuilders require is a steel which can be reliably welded with the exercise of ordinary precautions and reasonable care to the exclusion of any heat treatment. Existing standard specifications for structural steels were drawn up for use in riveted structures without regard to weldability as a primary characteristic and it may be that some revision could properly be made in such specifications with a view to obtaining a higher degree of weldability without any sacrifice of desirable physical properties and, of course, without any increase in cost. Some shipbuilders are specifying a maximum carbon limit in their steel orders, a desirable condition which is easily met but which will tend to the production of hull steel with the ultimate tensile strength well within the present allowable upper limit of the allowable tensile range of 60,000 lb. to 72,000 lb. per square inch.

Efficient design, suitable materials and sound welds will preclude the possibility of major structural failures in our large welded ships. It should also be emphasized that adequate supervision of welders and welding equipment, and close and intelligent inspection of the job are essential. Unfinished work is not so readily apparent as in riveted construction. That failures of welded structures are possible even where actual working loads are easily determinable is evidenced by the classic case of the welded bridge at Hasselt, Belgium, which collapsed after a short period of service for no apparent reason. The material of the bridge was "Thomas" steel, a basic Bessemer steel which is in common commercial use in Belgium and France, this particular process being dictated by the nature of the high phosphorus ore readily available. Due to the brittle nature of the fractures the failure was by some experts attributed to the general unsuitability of this material for welding. Others, including the steel manufacturers, had no hesitation in blaming the welding and naturally enough the design has also come under some criticism. Several samples taken from the ruins were made available to a Committee of the Institute of Welding and from their published report it would appear that some at least of the welded joints were quite unsatisfactory. Apparently the design, material and welding are all under suspicion and certainly inferior design, unsuitable material and poor welding make up a dangerous combination which need not exist throughout the whole job to become absolutely fatal to the structure.

The present trend of arc welding in our shipyards is toward the use of larger electrodes and heavier currents, continuous welding rather than intermittent and plain unstrapped butt joints rather than overlaps. In some applications the plate edges are unprepared. The tendency today is also to lay more stress on testing and approving processes and toward a simplification of tests for the so-called qualification of the welding operator which is all to the good. Our shipyards are continually experimenting with various types of automatic equipment and improved applications of the various processes may be confidently anticipated.

The importance of the research activities of the AMERICAN WELDING SOCIETY in the interests of sound and economical design of important structures such as welded ships cannot be overemphasized. Considerable research work of special interest to shipbuilders is being carried out in Great Britain involving full-scale experiments on both welded and riveted specimens of plate and shape combinations, necessitating the use of special testing equipment which allows the application of loads up to 180 tons. This investigation is being financed by the shipbuilding interests jointly with the Institute of Welding. We in this country cannot afford to lag behind in research work of this kind which has a definite practical value. The activities of our own Welding Research Committee is limited only by the amount of funds placed at its disposal and I hope that our shipbuilders will see their way to contribute generously to the work of the Committee which is of national importance.

If this paper has given those members of the Society, who are engaged in other engineering fields, a better idea of the extent of arc welding now being applied in ship construction in the United States the primary purpose, for its preparation will have been achieved.


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**AMERICAN WELDING SOCIETY, 33 West 39th Street, New York**

# QUALIFYING WELDING OPERATORS for Important Work

By L. M. DALCHER*

THE purpose of this article is to present a general survey of the subject of welding operator qualification tests, and the qualifications required of welding operators for various types of work. Specifically it is intended to provide answers to the following typical questions which are constantly being asked of Society Headquarters: "Must I have a certificate or license to weld on airplanes (or pressure vessels, ships, structural work, piping, etc.)? What tests are required? Must we certify our welders for work on pressure piping? What qualifications must a welder have to work in a Navy Yard? Where can I take the examination?" The following summary contains general information relating to these questions, and indicates the sources from which it is possible to obtain further specific information.

## CODE REQUIREMENTS

The testing and qualifying of welding operators are almost always carried out for the purpose of complying with the requirements of a code or specification governing some particular type of work on which the operator is to be employed. Listed in Table 1 are some of the principal codes and specifications containing rules for qualifying welding operators.

Each of these codes contains specific provisions governing the procedure to be followed in qualifying welding operators for work under that code. Such provisions include: (*a*) the manner of supervising the tests, (*b*) the number and types of tests required, (*c*) the method of welding the specimens, (*d*) the method of testing the specimens, (*e*) the test results required, (*f*) provision for retests in the event of initial failure, (*g*) the period of effectiveness of qualification, and (*h*) the method of requalification. In some cases the codes prescribe a specific method of recording the results of the qualification tests, usually by means of a form or certificate to be filled out and filed with the employer. As one would expect, considering the differences in application of the various codes and specifications, no two codes are exactly alike in respect to their provisions for qualifying welding operators. It is therefore necessary, when seeking detailed information as to the types of tests required, method of test supervision, etc., to consult the specific code or specification governing the particular type of work to be done.

* Assistant Technical Secretary, AMERICAN WELDING SOCIETY.

**Table 1**

| *Type of Welding* | *Title of Code or Specification and Name of Sponsoring Organization* | *Field of Application* | *Source from Which Copy of Code May Be Obtained* |
|---|---|---|---|
| Aircraft | Navy Aeronautical Specification No. PW-2a—Process for Gas Welding Aluminum and Aluminum Alloys; Bureau of Aeronautics, Navy Dept. | Gas welding of aluminum and aluminum alloys in wrought, extruded or cast form | Manager, Naval Aircraft Factory, Navy Yard, Philadelphia, Pa. |
| | Navy Aeronautical Specification No. PW-5a—Process for Gas Welding Magnesium Base Alloys; Bureau of Aeronautics, Navy Dept. | Gas welding of magnesium base alloys in wrought, extruded or cast form | Bureau of Aeronautics, Navy Dept., Washington, D. C. |
| | Navy Aeronautical Specification No. SR-43d—Process Specification for Gas Welding of Corrosion and Heat-Resisting Alloys; Bureau of Aeronautics, Navy Dept. | Gas welding of corrosion- and heat-resisting alloys (stabilized 18–8 type or "Inconel") | Bureau of Aeronautics, Navy Dept., Washington, D. C. |
| | Qualification Tests for Aircraft Welders (Steel Welding); Bureau of Aeronautics, Navy Dept. | Military aircraft, aircraft parts and accessories | Bureau of Aeronautics, Navy Dept., Washington, D. C. |
| | Welding Procedure for Certification of Welders; War Dept. Air Corps | Aircraft, aircraft parts and accessories | Chief, Materiel Division, Air Corps, Wright Field, Dayton, Ohio |
| General | Standard Qualification Procedure; American Welding Society | All types of gas and metal arc welding | American Welding Society, 33 West 39th St., New York, N. Y. (Price 25¢) |
| | Qualification Tests for Gas Welders (General Specifications for Inspection of Material, Appendix VII, Welding, Part E, Section E-2); Navy Dept. | All gas welding done for Navy Dept. | Bureau of Supplies and Accounts, Navy Dept. Washington, D. C.* |
| | Qualification Tests for Metal Arc Welders (General Specifications for Inspection of Material, Appendix VII, Welding, Part E, Section E-1); Navy Dept. | All metal arc welding done for Navy Dept. | Bureau of Supplies and Accounts, Navy Dept., Washington, D. C.* |

* Available only to contractors or prospective contractors for Navy work.

**Table 1**—(*Continued*)

| | | | |
|---|---|---|---|
| Machinery | Code for Arc and Gas Welding and Gas Cutting in Machinery Construction; American Welding Society | Machinery and industrial equipment | American Welding Society, 33 West 39th St., New York, N. Y. (Price 25¢) |
| Marine | Bureau Circular No. 235—Qualification and Requalification of Welding Operators; Bureau of Marine Inspection and Navigation, Dept. of Commerce | Marine boilers and pressure vessels, marine piping, and hull construction | Bureau of Marine Inspection and Navigation, Dept. of Commerce, Washington, D. C. |
| | Rules for Building and Classing Steel Vessels; American Bureau of Shipping | All parts of ships | American Bureau of Shipping, 24 Old Slip, New York, N. Y. (Price $5.00) |
| | Rules for the Fusion Welding of Hulls and Hull Parts (A. W. S. Marine Code for Welding and Gas Cutting — Part D); American Welding Society | Hulls and hull parts of merchant vessels | American Welding Society, 33 West 39th St., New York, N. Y. (Price 25¢) |
| | Rules for Fusion Welding Steam, Oil or Air Piping in Marine Construction; American Welding Society | High-pressure steam, oil or air piping for marine construction | American Welding Society, 33 West 39th St., New York, N. Y. (Price 25¢) |
| Piping | See specification listed immediately above | | |
| | Code for Pressure Piping; American Standards Association | High-pressure piping | American Welding Society, 33 West 39th St., New York, N. Y. (Price $1.00) |
| Pressure Vessels | A. P.-I. A. S. M. E. Code for Unfired Pressure Vessels for Petroleum Liquids and Gases; American Petroleum Institute and American Society of Mechanical Engineers | Unfired pressure vessels for petroleum liquids and gases | American Welding Society, 33 West 39th St., New York, N. Y. (Price 75¢) |
| | A. S. M. E. Code for Power Boilers; American Society of Mechanical Engineers | Power boilers for stationary service | American Society of Mechanical Engineers, 29 West 39th St., New York, N. Y. (Price $1.50) |
| | A. S. M. E. Code for Unfired Pressure Vessels; American Society of Mechanical Engineers | Unfired pressure vessels | American Welding Society, 33 West 39th St., New York, N. Y. (Price 75¢) |
| Structural (Bridges) | Specifications for Welded Highway and Railway Bridges; American Welding Society | Highway and railway bridges | American Welding Society, 33 West 39th St., New York, N. Y. (Price $1.00) |
| Structural (Buildings) | Code for Fusion Welding and Gas Cutting in Building Construction; American Welding Society | Buildings | American Welding Society, 33 West 39th St., New York, N. Y. (Price 25¢) |
| | Rules covering the Specifications for Design, Fabrication and Inspection of Fusion Welded Structures and the Qualification of Welders and Supervisors (New York City Building Code) | Buildings in New York City | Board of Standards and Appeals, Municipal Bldg., New York, N. Y. |
| Structural (Tanks) | Rules for Field Welding of Storage Tanks; American Welding Society | Storage tanks of the above-ground type for holding liquids at pressures not over 15 psi | American Welding Society, 33 West 39th St., New York, N. Y. (Price 25¢) |
| | Specification on All-Welded Oil Storage Tanks; American Petroleum Institute | Oil storage tanks | American Petroleum Institute, Division of Production, Dallas, Texas (Price 75¢) |

## A. W. S. STANDARD QUALIFICATION PROCEDURE

In 1934 the AMERICAN WELDING SOCIETY appointed a committee to formulate a Standard Qualification Procedure, which it was hoped would be adopted by all the major code-writing bodies, thereby eliminating the wide discrepancies then existing between the qualification methods of the various codes. This committee, known as the Committee on Standard Qualification Procedure, completed its first report in 1936 and has since issued two revisions, one in 1938 and one in 1940, the present title being "Standard Qualification Procedure—Section I—Manual Arc and Gas Welding of Ferrous Materials." Part I of this report prescribes the method of qualifying a welding procedure and Part II prescribes the method of qualifying welding operators.

Before the Committee on Standard Qualification Procedure was organized, most codes and specifications required that the tests of a welding operator include tests of the tensile strength and ductility of the weld. The committee recognized, however, that these properties were determined mainly by the particular procedure of welding employed, and that the welding operator had control only of fusing the weld metal to the base material and keeping the weld free from slag and porosity. Consequently the AMERICAN WELDING SOCIETY'S Standard Qualification Procedure has specified only soundness tests for the qualifying of welding operators, and each revision has seen a further simplification of the test requirements.

The provisions of the Standard Qualification Procedure have already been incorporated in many of the more important codes, including the A. S. A. Code for Pressure Piping, the A. S. M. E. Codes for Power Boilers and Unfired Pressure Vessels and all AMERICAN WELDING SOCIETY codes and specifications. It is anticipated, also, that most of the other code-writing bodies will adopt the Standard Qualification Procedure when revising their present standards.

## INSPECTION AGENCIES

The supervision and conducting of qualification tests have been made a commercial enterprise by a number of

reputable organizations, including testing laboratories, consulting engineering firms and some insurance companies. In most cases this supervision is exercised as part of the shop inspection of boilers, pressure vessels, pipe lines and other assemblies fabricated under code regulations. The clients of these organizations are chiefly manufacturers or contractors who utilize the services and facilities of the inspection agencies in complying with the qualification requirements of the various codes and specifications. The codes most frequently encountered in this connection are the A. W. S. Code for Fusion Welding and Gas Cutting in Building Construction, the A. S. A. Code for Pressure Piping and the A. S. M. E. Codes for Power Boilers and Unfired Pressure Vessels. Occasionally a concern will hire an inspection agency to conduct tests of their welding operators, not because they are required to do so by any code or customer's specification, but simply to provide a partial check on the quality of their welded work. In such cases the tests are almost always conducted in accordance with the A. W. S. Standard Qualification Procedure. In this connection there is one important point which deserves to be specially emphasized, namely: *the fact that a qualified welding operator has been employed is not, of itself, assurance that a given job has been satisfactorily welded.* For such assurance it is necessary to know, in addition, that a qualified *procedure of welding* has been employed and that the welds themselves have been carefully inspected.

When one of these organizations is called upon to certify that an operator has qualified under a certain code or specification, they witness the welding of the specimens (usually at the client's plant or on the job site in the case of field work), mark them for identification and witness the testing either in their own laboratory or on any equipment known to be accurate. If the results of the tests comply with the code requirements, a report or certificate stating that fact is issued *to the employer.* In some cases employers have given copies of the certificates to the welding operators as their credential to do work on some specified undertaking.

As a rule qualification tests for code work are not carried out independently for the welding operator. All authoritative codes require the manufacturer or contractor to be responsible for any welding work done, and some codes (for example, the A. S. M. E. Code for Unfired Pressure Vessels) specifically state that tests conducted by one employer do not qualify a welding operator to work for any other employer. This is generally interpreted to mean that tests conducted for the welding operator will not entitle him to do work under these codes without making new tests under his new employer.

## REQUIREMENTS FOR GOVERNMENT EMPLOYMENT

Welding operators employed in various branches of the federal government (Navy Department, War Department, National Advisory Committee for Aeronautics, etc.) are selected from registers of eligibles established as a result of civil service examinations. These examinations require no written or practical tests. Instead the applicants are rated on the quality and quantity of their experience and fitness, based on the competitors' sworn statements in their applications and upon verification thereof. After appointment, however, the welding operator is given a trial period of prescribed length in which to pass certain qualification tests or otherwise demonstrate his ability to perform the quality of work required.

There are several types of tests which the welding operator may be required to pass in order to retain employment, depending upon the nature of the work to be performed. For example, all steel welders accepting employment at a Navy Yard are required to pass a guided-bend test (root- and face-bend specimens) in the positions to be encountered on the particular job. For another type of work in a different branch of the government, the operator is required to make "a sample butt and fillet weld which will be checked for penetration, undercutting, porosity, size and appearance of bead." Such requirements are usually stated in the announcement of the examination.

The qualifications necessary in order to file an application are stated in the announcement of the examination, and differ according to the duties of the position to be filled. The principal requirement is length and type of welding experience. For gas welding this is usually two years; for electric welding it may be two years, or sometimes six months *on vertical and overhead work;* for aircraft welding the requirement may be four years "on sheets, tubes and rods of aluminum, copper, brass, iron and steel, and their alloys." Other qualifications ordinarily specified are that the applicant be a citizen of the United States, that he be well developed physically and in sound health, that he be between certain ages (20 and 48 or 18 and 50, usually), that he be able to speak and read English, and that he be at least 60 inches tall and 100 pounds in weight.

Civil service examinations for the position of welding operator are held from time to time as the needs of the service require. Announcements thereof are posted in first- and second-class post offices and given publicity in the newspapers. Applicants desiring to be notified of the examinations should so advise the office in which they desire appointment or the Manager of the Civil Service District having jurisdiction over that office.


## ACKNOWLEDGMENT

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# SCOPE AND LIMITATIONS OF Stored Energy Type Spot-Welding Equipment*

By G. S. MIKHALAPOV† and C. N. WEYGANDT‡

## INTRODUCTION

CONSIDERABLE interest has been lately aroused in the method of spot welding aluminum and its alloys wherein the energy necessary for the completion of the weld is stored in certain finite quantity either electro-magnetically or electro-statically or a combination of both and released in a very brief time at the formation of the weld. Actually this method of welding is probably the oldest known form of spot welding, the original spot-welding patent taken by Elihu Thompson in the end of the last century covering this process. For a long time it has been regarded with disfavor because of a number of inherent practical difficulties and also because of apparent lack of advantages over conventional A.C. method of spot welding.

With the advent of aluminum alloys it soon became apparent that the conventional A.C. method of spot welding was not entirely satisfactory for welding aluminum alloys. However, no attempt to use stored energy type method of welding for welding aluminum alloys had been made in this country until last summer when a French manufacturer introduced a fully developed machine utilizing this principle and advocated for use on aluminum alloys.

It soon became apparent that this machine produced a weld which appeared to be more homogeneous and less porous as well as more free from fine cracks which for so long have been troubling conventional aluminum alloy spot welding. A number of reasons have been suggested why the new application of this old process should be advantageous for use on aluminum and its alloys. The manufacturer himself claims that his success is due to a combination of factors present on his machine as well as to the quality of the workmanship exhibited by his equipment. However, it would appear that the principal reason for the improvement of the weld quality produced by his equipment is due to the stored energy principle which he employs.

A full theoretical discussion of the reasons for the superiority of the stored energy principle would require considerable space and does not rightly fall within the scope of this paper. The principal reason has undoubtedly to do with the extremely high rate of energy generation possible when electro-magnetic or electro-static charge is suddenly dissipated in the weld and the absence of the cooling period present during the reversals of the current occurring in alternating current circuits.

A thorough understanding of the relationship between the weld quality and the rate of heat generation and dissipation in the weld will have to wait until proper research can be conducted and a thorough study of the relationship between these two is made. There is undoubtedly an optimum value which will eventually be universally used. The present investigation does not attempt to fulfil the above task but is confined to the study of practical means by which the storage and sudden dissipation of energy can be produced and controlled.

Although the first is of the utmost importance to the industry in so far as its primary interest is in the quality of welding, it cannot be undertaken or solved without a thorough understanding and knowledge of the second. Proper tools must be first studied and designed before their use can be thoroughly developed. It is thus inevitable that the first step in the better understanding of the problem of welding aluminum will be confined to the study of characteristics of the equipment with which the stored energy type of welding can be performed.

Accordingly this investigation represents an attempt to study and present the various factors affecting the quantity, quality and control of the electric energy which can be stored by electro-magnetic means.

The present paper confines itself primarily to the study of electro-magnetic form of energy storage in so far as a separate investigation is being made to cover the electro-static energy storage field.

## SUMMARY OF CONCLUSIONS

As a result of the present investigation the following general conclusions appear to be in order:

1. The practical application of the electro-magnetic energy storage is limited to cases where relatively small quantities of energy are required. The limiting factor is the physical bulk of iron necessary to store energy as the maximum amount of energy that can be practically stored in, and recovered from, an electro-magnetic circuit in a form suitable for welding is between two and two and one-half watt seconds per pound of iron. In round figures this means that a storage transformer unit capable of delivering 10 kilowatt seconds at a time would contain 5000 lb. of iron and approximately 1000 lb. of copper.

2. The best method of controlling energy stored in an electro-magnetic circuit is by means of an electronic switching device such as an ignition type tube and a small auxiliary capacitor.

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3. The use of mechanical switches as means for recovering energy stored in an electro-magnetic circuit is unsatisfactory, as it introduces possibility of weld inconsistency with tip wear, presents a serious maintenance problem and limits possible speed of current generation.

4. Whenever a relatively small quantity of high power energy is desired, which can be utilized in a comparatively fixed form in so far as the duration of its peak value is concerned the electro-magnetic storage with proper electronic control provides a simple and inexpensive method of welding.

5. Whenever any degree of control of the duration of the secondary current at or near its peak value is desired the electro-magnetic storage method should not be used.

## THEORY OF ELECTRO-MAGNETIC STORAGE

The flow of electrical current through any conductor produces a magnetic disturbance in the immediate vicinity of the conductor which is known as the electro-magnetic field of the current. It requires a definite quantity of energy to produce this disturbance, or field, and this energy must be expended before the current can be made to flow. However, once expended it can be regarded as being stored in the field and if an attempt is made to diminish or stop the flow of current this stored energy will assert itself by attempting to maintain the flow. There are no losses in this transaction, whatever is put in is recovered, though, naturally, no more energy can be recovered from the field than has been put in it. However, the rate at which the energy can be stored in the field, and the rate at which it can be recovered from it, can be widely different. Thus, it is possible to store a comparatively large quantity of energy in a field at a low rate, or at low power, and then recover it or dissipate it, in a very brief time—that is, at comparatively high power.

The above phenomena of the electro-magnetic field are the basis of electro-magnetic storage welding.

The simplest way of producing a large electro-magnetic field is to have direct current flowing through an inductive circuit such as would be present, for instance, in a coil of wire. The higher the magnitude of the current, and the greater the actual volume of the coil as well as the number of its turns, the greater will be the amount of energy which would be stored in this field.

Once the field is established it requires no energy other than that used in overcoming the resistance of the current-carrying conductor to support this field. The moment the current maintaining the electro-magnetic field is arrested the field collapses and the energy which was stored in the field is dissipated in some form or another.

If a single turn of wire is provided at right angles to the collapsing field the energy of the field will be transmitted to this turn of wire in the form of electrical current which will flow in the wire in such form as to attempt to prevent the collapse of the field. If the resistance of the conductor is made comparatively low the current produced will be extremely large, and in this fashion a form of welding transformer is obtained.

It can be seen, therefore, that a device for storing electro-magnetic energy and suddenly discharging it at a high rate is provided by a welding transformer through which direct current is first made to flow and then suddenly interrupted. The sudden arrest of the current flow produces a rapid collapse of the transformer field which induces a heavy current in the single secondary winding. There is one distinct feature in a transformer used for such purpose which must be maintained if the magnitude of the energy stored is to be at all appreciable. This feature is made necessary by the fact that the energy which can be obtained in the collapsing electro-magnetic field is equal to that which is put into this field, and consists of increasing the magnetizing force by introducing an air gap or, preferably, a series of air gaps into the iron circuit of the transformer. The effect of this air gap is to increase greatly the force necessary to establish the electro-magnetic field and thus to increase the energy storage capacity of the field. In addition it is also necessary to provide the storage type transformer with a higher ratio of turns than is customary in a standard welding transformer.

Apart from the above two differences the energy storage transformer is similar in practically every respect to a conventional welding transformer and is thus a comparatively simple piece of apparatus.

However, the equipment necessary to produce and control the changes in the electrical current requisite for recovering the energy stored in the electro-magnetic field requires considerable study as it must perform an inherently difficult job.

As stated before, it is the collapse of the magnetic field

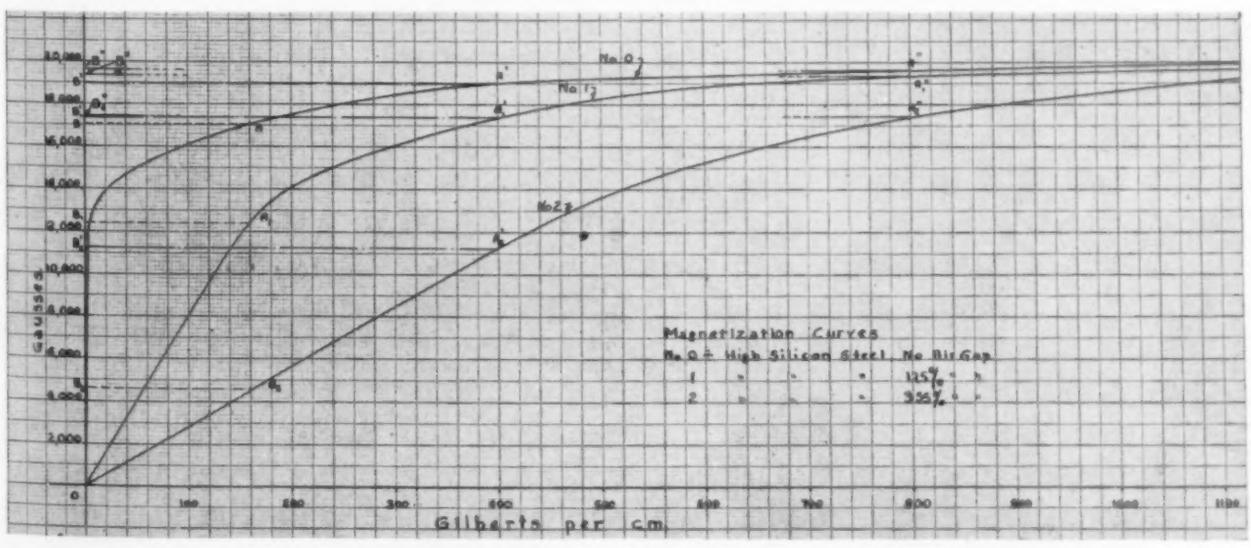



Fig. 1—Magnetization Curves for High Silicon Steel Cores with No Air Gap and 1.25% and 3.55% Air Gaps, Respectively

which induces potential in any conductor passing at right angles to the field. If only one conducting circuit, the primary circuit, through which the current normally supporting the field is passing were present, the energy of the collapsing field would all be dissipated in the primary circuit, more specifically in the opening which started the collapse of the field. It would then be impossible to interrupt the current without dissipating the entire energy of the field at the point of interruption in the form of an arc.

If, however, a second closed conducting circuit, closely paralleling the first circuit, is provided, a part of the energy of the collapsing field can be dissipated in the secondary circuit in form of current. If it were possible to have the primary and secondary circuits occupy the same space, that is, were it possible for all the magnetic flux linking the primary, to link also the secondary, the entire stored energy could be transmitted to and thus recovered in the secondary circuit without causing an effort on the part of the primary current to maintain its own flow. Since, however, such physical coincidences on the part of two independent circuits are impossible there is always a certain amount of leakage flux linking one circuit but not the other which will attempt to maintain the flow of primary current only, and will obstruct its interruption.

The extent of this leakage flux determines the difficulty of interrupting the primary current and thus indirectly governs the quantity of energy that can be stored in the field.

The second factor affecting the difficulty of interrupting the primary current is the rate of interruption. The higher the rate the more rapid the voltage rise across the break, and consequently the higher the rate of growth of the secondary current.

From a welding point of view it is usually desirable, especially when welding thin sheets, to produce an extremely high rate of current rise. It becomes then important to be able to interrupt the primary current not only with the minimum of loss but also in the minimum of time. In the extreme hypothetical case of zero time of interruption the voltage across the break becomes infinite. This is obviously an impossibility but it is indicative of the difficulties presented by the problem.

Since it is impossible to interrupt the current in zero time a certain loss at the point of interruption is inevitable unless instead of attempting to break a flow of current it is diverted to a kind of blind alley where it can for a brief period pile up on itself coming to a stop gradually and eventually reversing itself and flowing backward. Such a condition exists when a path containing a condenser is offered to the current as an alternate to the path being interrupted, as shown in Fig. 4, in which case the current that would have been dissipated in the interruption is absorbed by the condenser in form of a charge and is subsequently recovered.

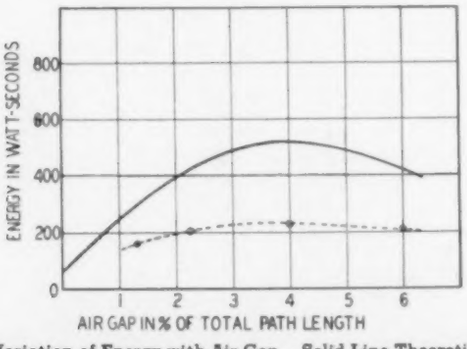
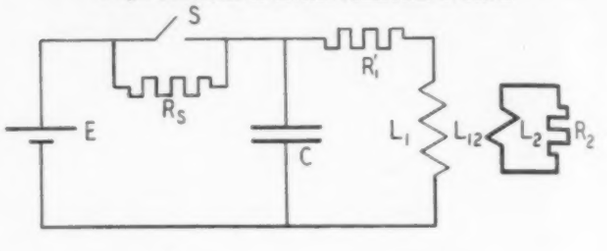



**Fig. 2—Variation of Energy with Air Gap. Solid Line Theoretical Value of Total Energy Stored in Transformer of Set-Up E. Dotted Line Experimental Values of Energy Recovered in First Loop of Current, Tube Interruption**

**Fig. 3—Wiring Diagram for Contactor Interruption. *S* Was Either a Single Contactor or Several Contactors in Series**



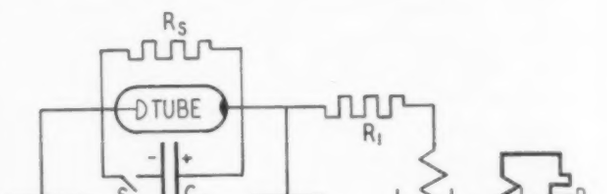




**Fig. 4—Wiring Diagram for Tube Interruption. None of the Tube Auxiliary Circuits Are Shown**

## ENERGY CAPACITY OF ELECTRO-MAGNETIC FIELD

The discussion so far has been a generalized explanation of the fundamentals involved in electro-magnetic storage welding and is intended to give some understanding of the phenomena involved. In practical application, however, it is necessary to be able to determine the quantities of energy and the magnitude of current and voltage involved, and for this reason a mathematical approach to the problem becomes essential. A full mathematical analysis of the problem involved is given separately in the Appendix and reveals that the equations giving the relationship of time, current voltage and the physical constants of resistance and inductance remain comparatively simple as long as inductance remains a constant and does not become a function of the current.

Unfortunately in practical cases the above condition seldom exists, as in order to improve the magnetic coupling between the secondary and primary circuits and decrease leakage flux it becomes necessary to introduce iron into the circuit.

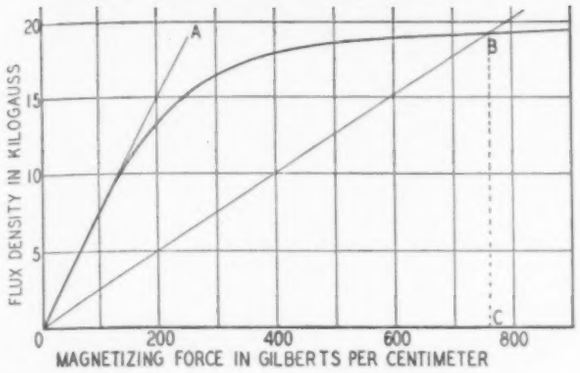
This in itself would not produce a variable inductance were it not for the fact that in order to utilize the iron most efficiently it becomes frequently advisable to use electro-magnetic fields beyond the saturation point of iron, and thus beyond the point where inductance ceases to be constant and becomes a function of the current.

The equations at this point become extremely complicated and an exact solution is practical only by means of mechanical or electrical differential analyzer. In practice, however, a number of approximations can be made and a fairly accurate set of formulas can be derived, such as given by equations 46, 47 and 48 of Appendix.

A very good graphical method can be used to determine the energy capacity of any electro-magnetic field containing iron or other material of variable permeability. This method has considerable practical use and is, therefore, given below in some detail as follows:

Figure 1 shows a magnetization curve for high silicon grade of electric steel plotted as density in gausses or

Fig. 5—Method of Obtaining Saturation Factor



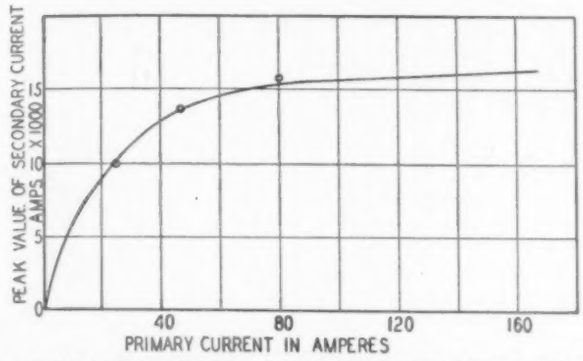




Fig. 6—The Relation Between the Peaks Secondary Current and the Primary Current for a Specific Circuit *F* (See Table 2) Showing the Effect of Saturation of the Core

lines per square centimeter against oersteds or gilberts per linear centimeter. Curve 1 represents a closed iron path without any air gap. The magnetic energy contained in a cc. of iron in that circuit at any flux density, $B$, is

$$W = \frac{10^{-7}}{4\pi} \int HdB \text{ watt-seconds}$$

This expression is given by the area $OBA$. A further increase in flux density from $B$ to $B'$ will increase the energy per cc. by area $BAA'B'$ for a total of $OB'A'$. These two areas when measured give values of 0.0023 watt-second and 0.0073 watt-second, respectively. To get the total energy stored in the iron these quantities must be multiplied by a total volume in cc. of the transformer core.

It will be seen that by increasing the magnetizing force from 160 gilberts per centimeter to 400 gilberts per centimeter or approximately 150%, an increase of energy of approximately 200% is accomplished.

If, however, we increase the magnetizing force still further from 400 gilberts per centimeter to 800 gilberts per centimeter or an additional 100%, the additional area gives an energy increase of only 0.00275 watt-second or 38% increase.

There is thus a definite limitation to the amount of energy that can be stored in an iron circuit by increasing the magnetizing force.

A closed iron circuit as shown by Curve 1 does not, however, represent the most efficient way of utilizing electro-magnetic storage capacity. A brief inspection of the curve reveals that area $OBA$ or $OB'A'$ could be greatly increased if points $AO$ or $A'O$ were connected by a straight line instead of a curve. At present there is no metal possessing such linear magnetizing characteristics; however, some approximation of it can be made by judicious introduction of an air gap or a series of air gaps into the magnetic circuit. An approximate magnetization curve for any magnetic circuit containing an air gap can be found by means of the following equation:

$$H = Bm + H_{FeB}(1 - m)$$

where

$$m = \frac{\text{length of air gap}}{\text{length of mag. circuit}}$$

$H_{FeB}$ = Mag. force necessary to produce density $B$ in iron

provided the length of any single air gap is small compared to its cross section. Curves 2 and 3 are magnetizing curves for iron circuits containing air gaps 1.25% and 3.55%, respectively, of their lengths.

Referring to Curve 2 area $OA_1B_1$ corresponding to the same magnetizing force as area $OAB$ now gives a unit energy of 0.0077 watt-second per cc. as compared to the original 0.0023 watt-second per cc., or an increase of 191%. Comparing areas $OA'_1$ to $B'_1$ with $OA'B'$ we have an increase of 189% from 0.0073 watt-second per cc. to 0.021 watt-second per cc.

With a still greater increase in air gap even greater quantities of energy can be stored per unit volume provided greater magnetizing force is used. For instance, both areas $OA_2B_2$ and $OA'_2B'_2$ on Curve 3 are actually smaller than $OA_1B_1$ and $OA'_1B'_1$, respectively, and it is not until point $A''$ is reached that an appreciable increase in energy is reached.

Since the unit energy of magnetic circuit appears to increase consistently with the simultaneous increase of air gap and magnetizing force, it would appear that the process could be continued indefinitely, or at least until the entire iron part of the circuit is replaced by air. However, at that point most of the usefulness of the magnetic storage method would disappear as the primary kva. necessary would assume the same magnitude as in a conventional A.C. welder.

In practice, however, the maximum field intensity is limited by the allowable voltage rise across the circuit opening switch, that is, by the difficulty to effect the interruption at high values of magnetization. As explained later the maximum field intensity which at this time appears practical based both on the theoretical calculations and experiments conducted in this investigation is about 800–1000 gilberts per centimeter or, roughly, 1600–2000 ampere turns per inch of iron circuit.

Table 1

| Air Gap | Mag. Force $H$ | Energy | Mag. Force $H$ | Energy | Mag. Force $H$ | Energy |
|---|---|---|---|---|---|---|
| None | 160 Gl./Cm. | 0.0023 W.-S./Cc. | 400 Gl./Cm. | 0.007 W.-S./Cc. | 800 Gl./Cm. | 0.010 W.-S./Cc. |
| 1.25% of total length | " | 0.0077 " | " | 0.021 " | " | 0.031 " |
| 3.25% " " " | " | 0.0031 " | " | 0.0193 " | " | 0.0440 " |
| 3.55% " " " | " | 0.0027 " | " | 0.0179 " | " | 0.0460 " |
| 4.00% " " " | " | 0.0026 " | " | 0.0159 " | " | 0.0461 " |
| 4.50% " " " | " | 0.0023 " | " | 0.0142 " | " | 0.0463 " |
| 5.00% " " " | " | 0.0020 " | " | 0.0127 " | " | 0.0455 " |

It will be seen from Table 1 that the maximum possible energy storage at 800 gilberts per centimeter is 0.046 watt-second per cc. or 2.7 watt-seconds per pound of iron used. In practical design a slightly lower figure should be used to provide for the losses incurred in recovering the energy from the electro-magnetic field. These losses will vary depending on the method of recovery and design from 10 to 25%, and a conservative figure appears to be between 2.0 and 2.5 watt-seconds per pound of iron used.

## FACTORS LIMITING CAPACITY AND RATE OF CURRENT CHANGE

Theoretically an unlimited amount of energy could be stored in any electro-magnetic circuit simply by increasing the field intensity of the circuit. In practice, however, the maximum field intensity is limited by the difficulties encountered with the interruption of the primary circuit at high field intensity and to some extent by the economic limitations of providing a source of high-amperage direct current. Let us consider the extent of the voltage surge and its implications in the two methods of current interruption.

### (a) *Direct Interruption by Means of a Switch*

Equation 15 (see Appendix) gives the maximum voltage across the switch at an instant of interruption as equal to the D.C. voltage of the circuit times the ratio of the resistance across this switch to the resistance of the primary circuit of the transformer. This voltage will proceed to decay in direct proportion to the primary current. The variation of the primary current is given by equation 13 (see Appendix) which may be rewritten:

$$i_1(t) = \frac{E}{R_1}\left[1 + \frac{R_2}{2R_1}\left\{(1+A)\varepsilon^{-\alpha_1 t} + (1-A)\varepsilon^{-\alpha_2 t}\right\}\right] \qquad (52)$$

where

$$A = \frac{R_1L_2 - R_2L_1}{2\sqrt{\left(\frac{R_1L_2 - R_2L_1}{2}\right)^2 + R_1R_2L_{12}^2}} \qquad (53)$$

and $\alpha_1$ and $\alpha_2$ are given by equations 19 and 20.

Considering that $L_1 = n^2L'_1$, $L_2 = L'_1 + L_{20}$ and

$$L_e = \frac{n^2L_1L_{10}}{L'_1 + L_{10}} \text{ (see Appendix)}, \qquad (54)$$

$A$, $\alpha_1$ and $\alpha_2$ can be expressed as follows:

$$A = \frac{R_1L_2 - R_2n^2L'_1}{2\sqrt{\left(\frac{R_1L_2 - R_2n^2L'_1}{2}\right)^2 + R_1R_2n^2(L'_1)^2}} \qquad (55)$$

$$\alpha_1 = \frac{\frac{R_1L_2 + R_2n^2L'_1}{2} - \sqrt{\left(\frac{R_1L_2 - R_2n^2L'_1}{2}\right)^2 + R_1R_2n^2(L'_1)^2}}{n^2L'_1L_{20}} \qquad (56)$$

$$\alpha_2 = \frac{\frac{R_1L_2 + R_2n^2L'_1}{2} + \sqrt{\left(\frac{R_1L_2 - R_2n^2L'_1}{2}\right)^2 + R_1R_2n^2(L'_1)^2}}{n^2L'_1L_{20}} \qquad (57)$$

Equation (52) shows that the primary current is made up of two terms, which die at rates dependent on $\alpha_1$ and $\alpha_2$, respectively. Equation (14) in the Appendix shows that the secondary current builds up at a rate dependent mostly on $\alpha_2$ and dies out at a rate which depends mostly on $\alpha_1$. Therefore let us analyze the behavior of $\alpha_1$ and $\alpha_2$ when various circuit parameters are changed. Table 3 shows the effect of carrying some of these parameters to the limit.

**Table 3**

| | $L'_1 \to 0$ | $L'_1 \to \infty$ | $n \to 1$ | $n \to \infty$ | $R_2 \to \infty$ |
|---|---|---|---|---|---|
| $\alpha_1$ | $\frac{R_2}{L_{20}}$ | 0 | $\frac{R_2}{2L_{20}}$ | $\frac{R_1}{2L_e}$ | $\frac{R_2}{L_{20}}$ |
| $\alpha_2$ | $\frac{R_1}{n^2L'_1}$ | $\frac{R_e}{n^2L_{20}}$ | $\frac{R_1}{L_e}$ | $\frac{R_2}{L_{20}}$ | $\frac{R_1}{L_e}$ |
| $A$ | 1 | $\frac{R_1 - R_2n^2}{R_1 + R_2n^2}$ | 1 | −1 | 1 |

The values in the body of the table are those approached by the quantities in the left-hand column as the quantities at the head of the columns approach the limits indicated.

By substituting these limiting values in equations (13) and (52) the following general conclusions may be drawn:

1. Increasing the reluctance (proportional to $1/L'_1$) of the iron core increases the rate of decrease of the primary current and both the rate of increase and decrease of secondary current.
2. As $n$ increases the rate of decrease of the primary current increases but only from that corresponding to $R_2/2L_{20}$ to that corresponding to $R_2/L_{20}$ (see Fig. 9 (*a*)). As $n$ increases the rate of increase of the secondary current decreases, but this is offset by the fact that the magnitude of the secondary current increases directly with $n$. In practice $n$ is usually so large that $\alpha_2$ is nearly equal $R_2/L_{20}$.
3. In view of the last statement the rate of decrease of the primary current is nearly directly proportional to the secondary resistance and inversely proportional to the sum of the secondary loop and leakage inductances.
4. Even by increasing the resistance to infinity it is impossible to make the primary current decrease at a rate faster than that corresponding to $R_2/L_{20}$. This is

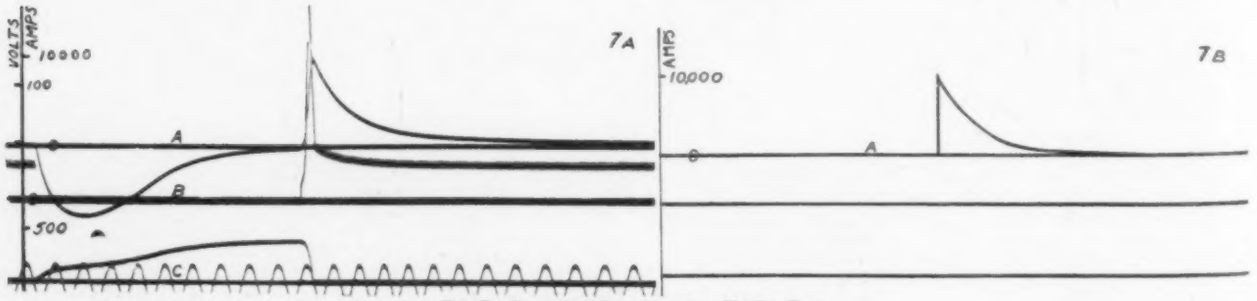



**Fig. 7—Contactor Interruption, No Air Gap**

(*a*) Oscillogram for set-up *A*
(*b*) Calculated current

Note that with no air gap the secondary current is almost as large when the primary current is established as when it is interrupted

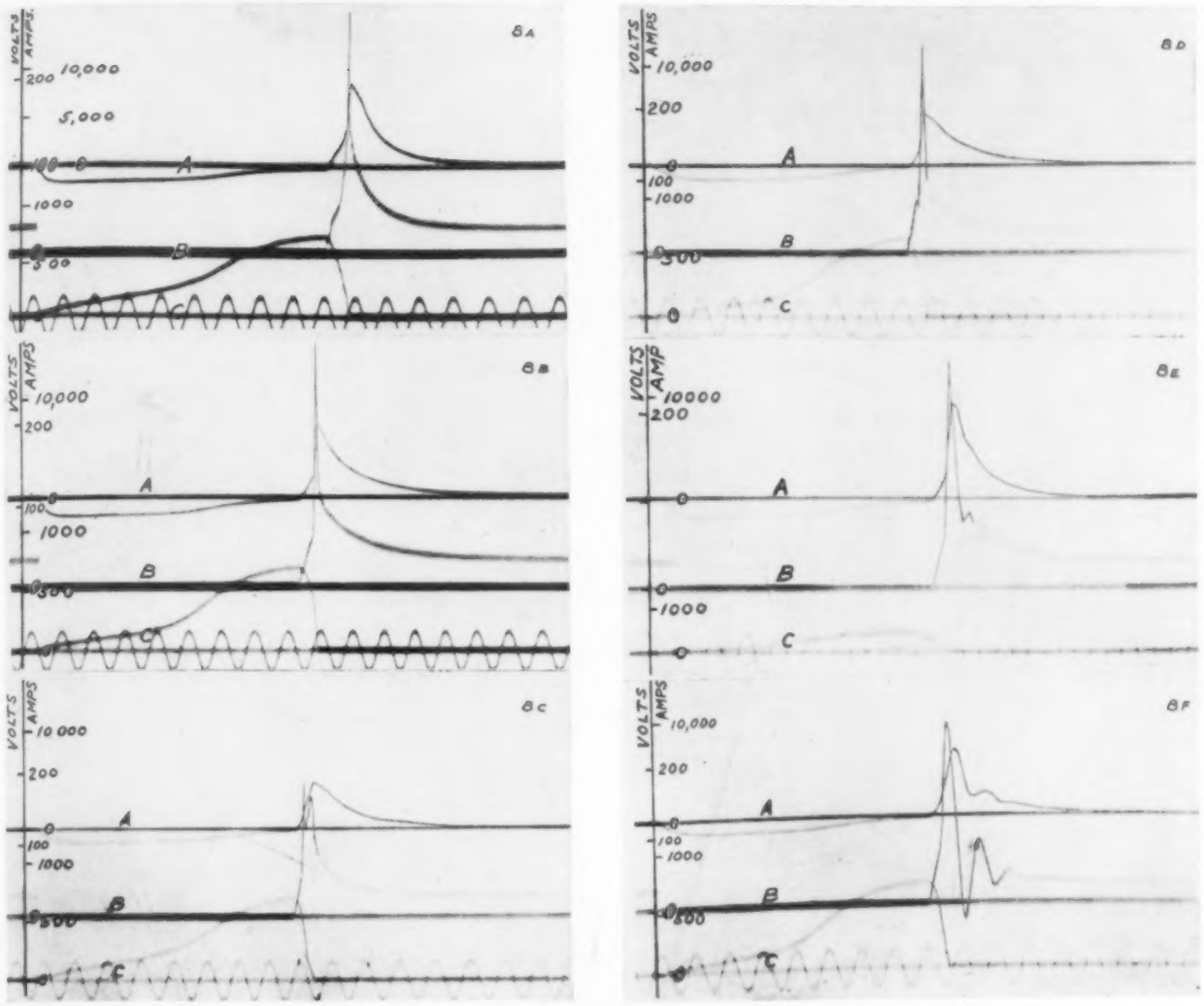



Fig. 8—Contactor Interruption, Effect of Varying Air Gap and Placing Capacitor in Parallel with Transformer, and Varying Length of Welding Loop

(a) Set-up *B*—1.29% air gap, no capacitor, short loop
(b) Set-up *C*—0.7% air gap, no capacitor, short loop
(c) Set-up *D*—1.29% air gap, no capacitor, long loop
(d) Set-up *I*—0.7% air gap, no capacitor, long loop
(e) Set-up *B*—1.29% air gap, 1840 mfds., short loop
(f) Set-up *I*—0.7% air gap, 1840 mfds., long loop
30-volt source, primary current before interruption 750 amperes in all cases

another way of saying that no switch can be designed that will instantly interrupt a d.-c. circuit if the inductance is not zero.

(*b*) *Interruption by Means of a Series of Switches*

Considering the effect of the secondary current when a series of increasing resistances are introduced into the primary circuit, equation (21) can be written

$$i_1(t) = \frac{E}{R_1} + \frac{1}{2}\left[i_1(0) - \frac{E}{R_1}\right]\left[(1+A)\varepsilon^{-\alpha_1 t} + (1-A)\varepsilon^{-\alpha_2 t}\right] + i_2(0)R_1L_{12}\left(\varepsilon^{-\alpha_1 t} - \varepsilon^{-\alpha_2 t}\right) \quad (58)$$

Comparing above equation with equation (52) we note that the only difference between them is the addition of term

$$i_2(0)R_1L_{12}\left(\varepsilon^{-\alpha_1 t} - \varepsilon^{-\alpha_2 t}\right) \quad (59)$$

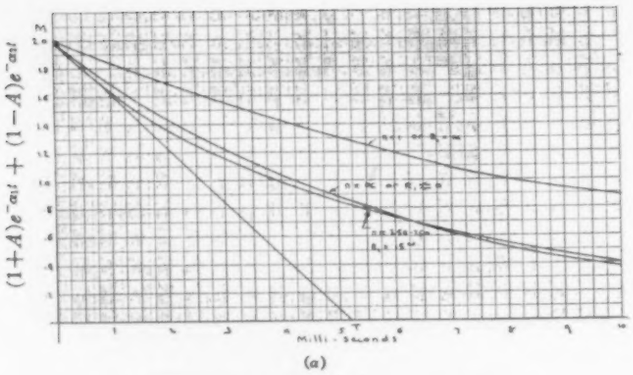
which represents the influence of a secondary current on the primary current.

Since $\alpha_2$ is always greater than $\alpha_1$ in equation 59 the effect of the secondary current is always to decrease the rate of decay of the primary current.

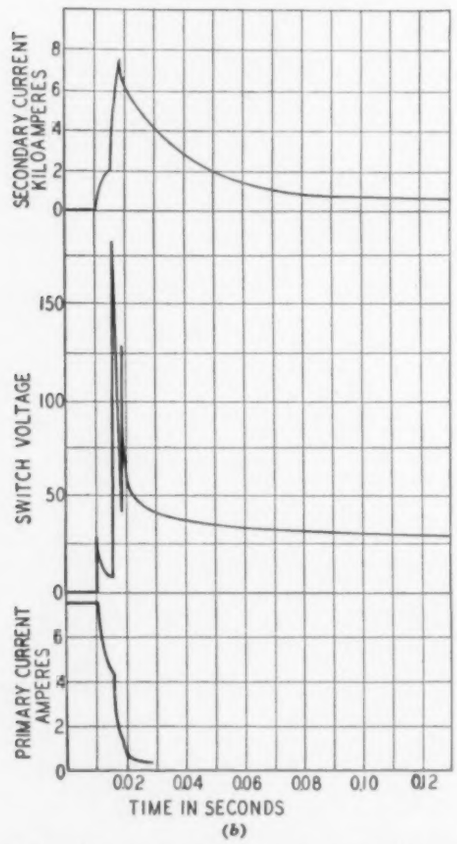
The difference in the decay of $\alpha_1$ and $\alpha_2$ is most pronounced when $n$ is low and decreases to some extent as $n$ increases; however, for practical limits of $n$ this change is slight. Similarly the value of $n$ has little influence on the effect of secondary current on the rate of decay of the primary current. Accordingly we can deduce further that the magnitude of the secondary current plays little importance in its effect on the primary current.

From the above we can see that the conclusions deduced on the basis of a single insertion of resistance into the primary circuit, in general, apply to the case of progressive insertion of increasing resistances into the primary circuit.

Analyzing the conclusions obtained above it becomes clear that the effective rate of decay of the current (the sum of two exponentials in equation 52) follows very nearly the same pattern at each successive increase of resistance as shown on Fig. 9 (*a*). It also can be observed from these curves that the rate of decay is most rapid at the beginning of each increase and, therefore, it can be concluded that the most rapid decay of the primary current would occur if the initial rate was main-




(a)




(b)

**Fig. 9—Calculated Currents and Voltages Corresponding to Fig. 8 (*b*). These Curves Were Calculated by Means of Equations 21 and 22, Assuming $R_e$ Was Inserted in Three Steps, 0.04, 0.4 and 0.56 Ohm at Times 0.01, 0.016 and 0.019 Second, Respectively**

tained to the end. This condition is approached by successive insertions of resistances as shown on Fig. 9 (*b*) and is represented approximately by tangent $MT$ on Fig. 9 (*a*).

Referring to Fig. 9 (*a*) the time $OT$ represents thus the absolute minimum time of interruption that can be accomplished on the particular circuit shown under ideal, practical conditions. Actually the minimum time is also contingent on the ability of the switch to withstand the rapid voltage rise across the switch opening without breakdown, as the breakdown means a reduction of the circuit resistance and return to the original rate of decay.

Thus, the higher the voltage that can be safely maintained across the switch the closer the approach to the minimum interrupting time. Since in actual practice the maximum voltage that can be maintained across the opening contacts of a commercial switch is limited to a few hundred volts the minimum practical interrupting time at present would appear to be two or three times that of the theoretical minimum.

The maximum field intensity practical with this method is limited, first, by the permissible magnitude of the primary current, and, second, by the physical limitations of placing more than a certain number of turns per unit length of core while still maintaining proper copper cross section for the necessary current. A further limitation is made by the fact that the arc blow-outs which form the basis of all present magnetic switches require certain minimum current for effective operation as demonstrated on Fig. 11.

### (*c*) *Tube-Capacitor Interruption*

In case of tube-capacitor interruption the only limit to the rate of interruption of the primary current, and hence to the rate of rise of the secondary current, is the permissible magnitude of the voltage rise.

From equation 42

$$v_s(t) = E + i_1(0)\frac{2L_e}{C\sqrt{R_e^2 + \frac{4L_e}{C}}}\,\varepsilon^{-\frac{R_e}{2}\sqrt{\frac{C}{L_e}}\tan^{-1}\frac{2}{R_e}\sqrt{\frac{L_e}{C}}} \qquad (60)$$

we can deduce as follows:

1. The surge voltage is approximately directly proportional to the square root of the equivalent inductance and inversely proportional to the square root of the capacitance.
2. The surge voltage is directly proportional to the turn ratio.
3. The surge voltage is inversely dependent on both secondary and primary resistances, though for most practical circuits the effect of the resistances is small.
4. The surge voltage is directly proportional to the primary current.

Since all electronic tubes of the type suitable for this work have definite limitations in both current-carrying and maximum surge voltage capacities, the magnetic field intensity is even more strictly limited than in the first case. However, since very much higher voltages are permissible than with the magnetic switch operation, about the same field intensity can be used without increasing necessary capacitance beyond a few microfarads.

In conclusion let us examine the effect of energy capacity on the ease of interruption of the primary current.

For any definite magnetic field intensity the energy capacity is given by the volume of iron in the core. The increased volume increases both $L_1$ and $L_2$ by increasing the ratio of cross-section area of the core to its total length in equation.

$$L = \frac{.4\pi \cdot 10^{-8} \cdot A\mu n^2}{l} \qquad (61)$$

and the only net effect is to change the relationship of $L'_1$ $L_{20}$ in equation 54. Therefore, in the first case the increase in energy capacity has practically no effect on the rate of primary current decay and, therefore, on the ease of primary current interruption. In the second case, however, increase of $L'_1$ over $L_{20}$ tends to increase slightly the value of $L_e$ as can be seen from equation 54. In practical application the increase is very small as $L'_1$ is always considerably greater than $L_{20}$.

It will, therefore, be seen that the results obtained with a small capacity transformer are comparable in every respect, except the magnitude of the secondary current, to those obtained on the large capacity transformer. In other words the magnitude of the secondary loop and

the magnitude of the magnetizing force determine all operating characteristics except the magnitude of the secondary current which is also dependent on the transformer capacity.

A distinction should be made between the intensity of magnetic field and the total magnetomotive force necessary to produce the desired intensity. While the former should not exceed the 800–1000 gilberts per centimeter figure used in this investigation the latter may be as much as double the force used in experimental transformer, to compensate for the increase in length of the magnetic circuit which would have to be made in course of increase in the volume of iron, and therefore the energy capacity.

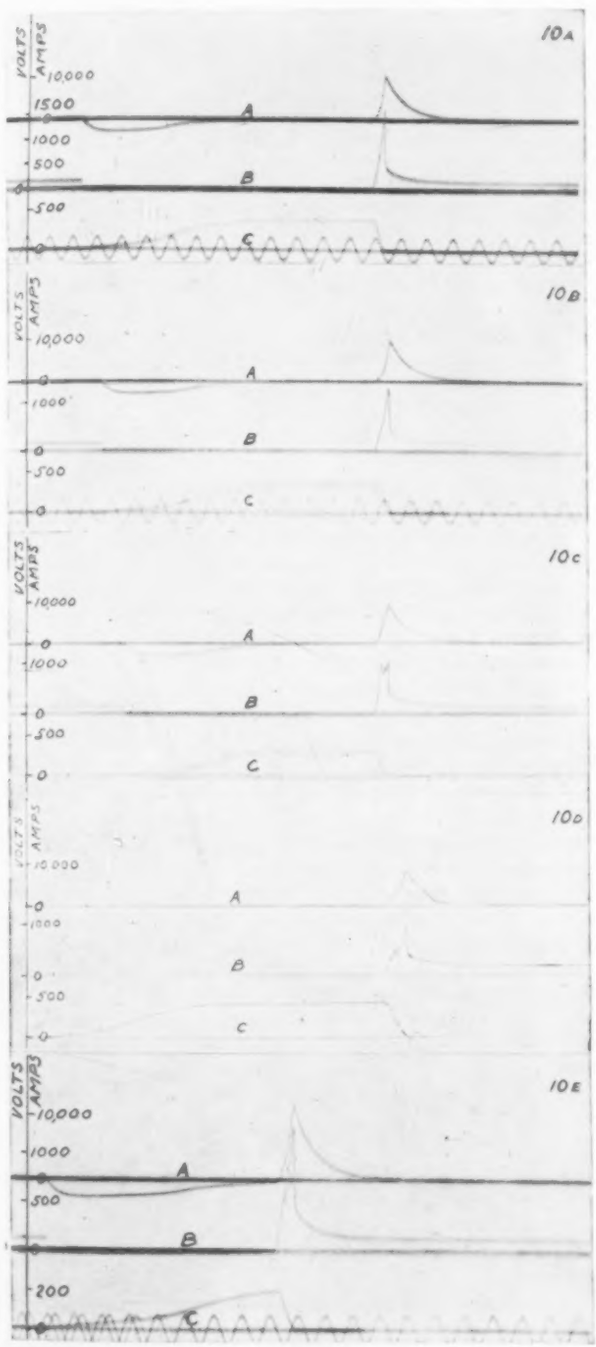



Fig. 10—Contactor Interruption, Effect of Different Contactor Arrangements

(a) Set-up G, four contactors in series opening in sequence, no resistors across contactors
(b) Same as (a) except 0.74 ohm resistor across first contactor to open
(c) Same as (a) except 2.42 ohm resistors across first two contactors to open
(d) Set-up G, single contactor
146-volt source, primary current 380 amperes in each of the above oscillograms
(e) Set-up H, four contactors in series opening in sequence, no resistors across any contactor, 112 volt source, primary current 200 amperes

## PRACTICAL MEANS OF RECOVERING ENERGY STORED IN AN ELECTRO-MAGNETIC FIELD

In practical application of electro-magnetic storage principle the most difficult and fundamental problem encountered is the proper interruption of the electrical current necessary for recovering the energy stored in the field. Since it is impossible to interrupt the current in zero time, certain means must be employed to reduce it gradually, yet in the shortest possible time, and with greatest uniformity between subsequent operations. The uniformity of operation is very essential, as any variation would result in variation of the secondary current and, therefore, in the quality of the weld.

The most direct way of interrupting any current is by opening the circuit mechanically and thus interposing the resistance of an air gap in the path of the current. Since separation of any two mechanical parts must perforce be gradual, arcing will result, and unless provision is made to snuff out the arc promptly a great deal of available energy will be dissipated in the arc. A mechanical switch designed to operate at extremely high speed and equipped with powerful blow-outs appears to give very good results in so far as time of operation is concerned, provided the electrical characteristics permit effective use of blow-outs, and provided a number of switches in series arranged to open in quick succession are used.

In this case the arc or arcs act as a rapidly increasing resistance inserted into the circuit which reduces the current to zero with rapidity based on the secondary inductance of the circuits as explained in the preceding section. Some very short interrupting times have been produced in this manner, as shown in Figs. 10*a* and 10*e*. In this case four high-speed welding contactors adjusted to operate in succession within 0.002 second of each other produce complete interruption in about 0.008 second. It is quite possible that, by the use of special design, still shorter time of interruption can be obtained.

A. B. Hendricks, Jr., and S. S. Maunder in an investigation conducted several years ago (page 241, *General Electric Review*, April 1930) report speed of interruption of 0.002 second with the use of a specially constructed toggle-type high-speed switch. However, the circuit used by them had little leakage inductance and no outside loop, and for this reason should have been inherently easy to interrupt (the current decay being very rapid) as is demonstrated by Fig. 7.

All mechanical current-interrupting methods present a problem of intense arcing which after sufficient number of operations may damage the tips to the point of interfering with the operation of the switch and therefore with the constancy of the weld. To overcome this problem and reduce the maintenance of the contact tips, another method wherein the resistance of the arcs is at least partially replaced with that of fixed resistors can be used. This method, the connections for which are shown in Fig. 3, is the one which is actually used at the present time on the only make of the electro-magnetic storage-welding equipment now on the market. It does appear to reduce the burning of the tips and thus reduce the maintenance problem, though this is accomplished at the sacrifice of the time of interruption, as the actual time

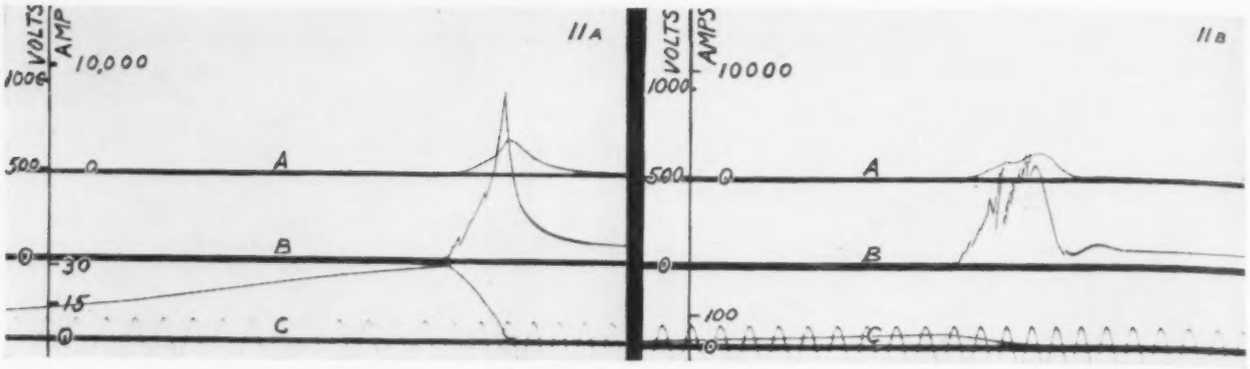



**Fig. 11—Contactor Interruption, Primary Current 30 Amperes, Turn Ratio 890, Set-Up E**

(*a*) Without capacitor
(*b*) With 115 microfarads in parallel with transformer
107-volt source in both cases
*Note:* Contactor operation is not satisfactory at low currents

of arcing appears to be if anything longer than the direct method, as seen on Figs. 10 (*b*) and (*c*). (It is also probable that slightly more energy is lost in this method than in the direct method.)

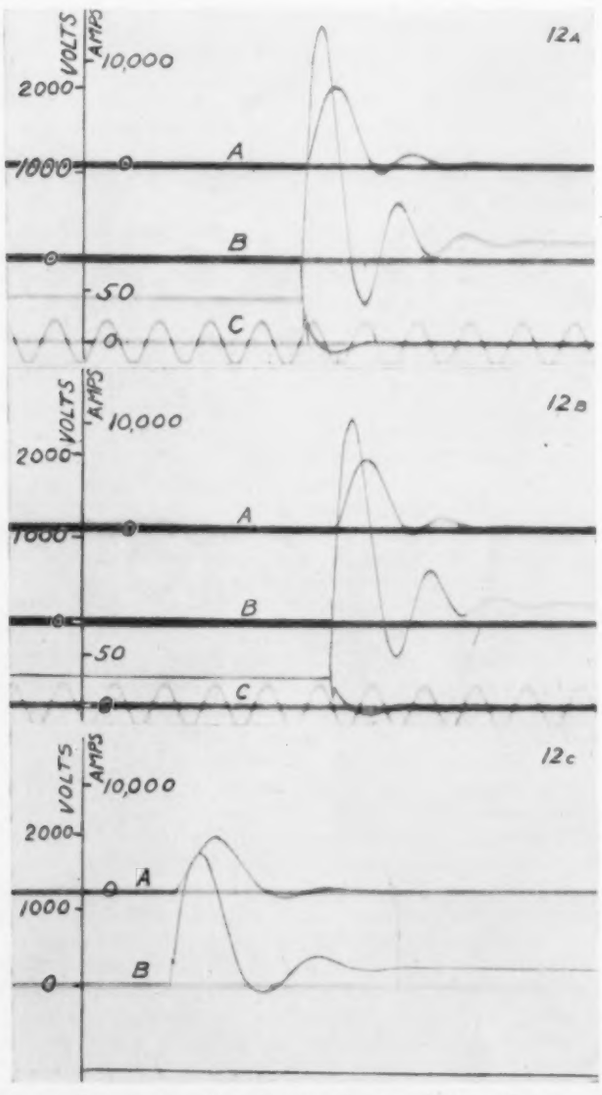



**Fig. 12—Tube Interruption, Effect of Varying Primary Current and Value of Capacitance**

(*a*) Set-up E, primary current 44 amperes, capacitance 27 mfd.
(*b*) Set-up E, primary current 30 amperes, capacitance 27 mfd.
(*c*) Set-up E, primary current 30 amperes, capacitance 54 mfd.
220-volt source in all cases

The insertion of resistance method has one other advantage in that it does not require the use of high-speed precision contactors which are necessary for effective direct interruption of current.

Either of the above two methods involves arcing and eventual burning and pitting of contacts with resulting uncertainty of operation and maintenance difficulties.

It has been long customary to introduce parallel condensers across the arcing points to reduce the extent of arcing. The effect of the condenser is to reduce the voltage across the separating points to zero at the instant of separation. Unless the condenser is extremely large it becomes fully charged in a very brief time and the voltage across the opening rapidly builds up to the point where, in most mechanical switches, the separation of the contacts which took place while the voltage was still low is insufficient to prevent arcing over at higher voltages. Accordingly the use of condensers on ordinary mechanical switches does not usually eliminate arcing to any large extent.

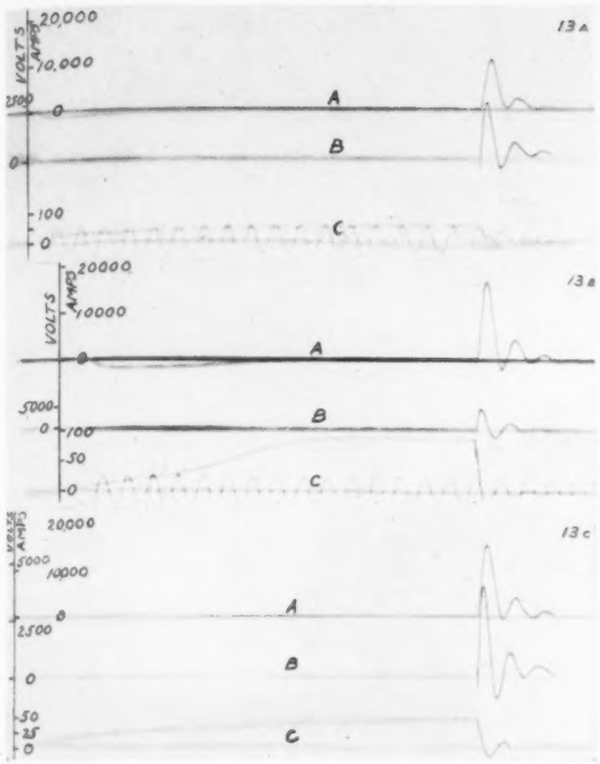
It is the comparatively slow speed of operation of any mechanical switch which causes it to fail to make use of the temporary reduction of voltage produced by the condenser. Figures 8 (*e*) and (*f*) show the effect, or, better, lack of effect, of introducing an appreciable condenser either across the switch or across the storage transformer with the interruption being done by a mechanical switch.

If, however, a mechanical switch is replaced by an electronic device capable of changing from current conducting to non-conducting state, within 0.0001 second or less, very satisfactory results can be obtained even with the use of a comparatively small condenser, as can be seen on Figs. 12, 13 and 14.

The speed of interruption and consequently of the rise of the secondary current is limited only by the magnitude of the permissible voltage surge in the primary circuit at the instant of interruption, which can be governed to some extent by the size of the capacitor used.

It can be clearly seen from the oscillograms obtained in this investigation that even with leakage inductance used which was equivalent to that of a secondary loop about as large as any of the loops now used on welding machines, comparatively small condensers up to 25 mf or 30 mf are sufficient to produce very satisfactory results both in so far as speed of rise is concerned and constancy of operation.

Although it is true that depending on the electrical characteristics of the transformer a varying amount of



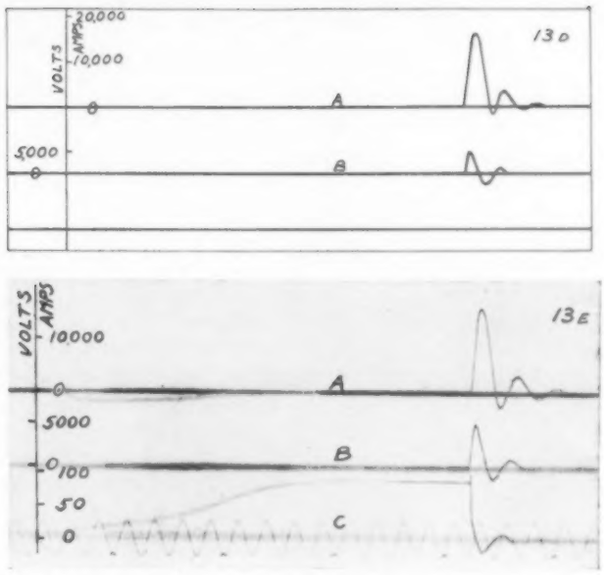




**Fig. 13—Tube Interruption, Effect of Varying Primary Current and Capacitance in Parallel with Transformer**

(a) Set-up F, primary current 25 amperes, capacitance 17.4 mfd.
(b) Set-up F, primary current 80 amperes, capacitance 17.4 mfd.
(c) Set-up F, primary current 50 amperes, capacitance 17.4 mfd.
(d) Calculated current and voltage corresponding to b
(e) Set-up F, primary current 80 amperes, capacitance 30.3 mfd.
230-volt source in all the above cases. Experimental values in Fig. 6 were taken from (a), (b) and (c)

energy stored in the field is lost in the primary side while the primary current flows in and out of the condenser this loss can be made comparatively small, that is, 10 to 20% and what is more it can be made exactly the same at each operation so that the constancy of operation is much better than with the use of a mechanical switch.

The absence of all mechanical operating parts and complete absence of all arcing reduce maintenance to practically nothing. Accordingly, this method appears to be eminently satisfactory and quite practical. It is true that a sinusoidal rather than an exponential wave is produced. There is no indication now available that this constitutes a disadvantage from the welding point of view. However, it is a comparatively simple matter to change decay of the current from sinusoidal to exponential by inserting a suitable resistance in parallel with the tube. This decreases the peak value of the secondary current and increases the losses but, when suitable compensations for this are made, provides an excellent method of not only securing an exponential decay but also of controlling the rate of the decay as shown on Fig. 15.

It must be remembered, however, that none of the above methods provides an easy or practical way of controlling the duration of the secondary current at or near its peak values. In fact, the only way this can be accomplished is by increasing the condenser several hundred times, and if this is done the chief advantage of the electro-magnetic storage method disappears and the electro-static method might be used just as well.

## EXPERIMENTAL RESULTS

In the course of the investigation leading to this paper a large number of oscillograms were taken, a few of which are presented here.

In some cases calculated curves have been plotted for comparison with the experimental results.

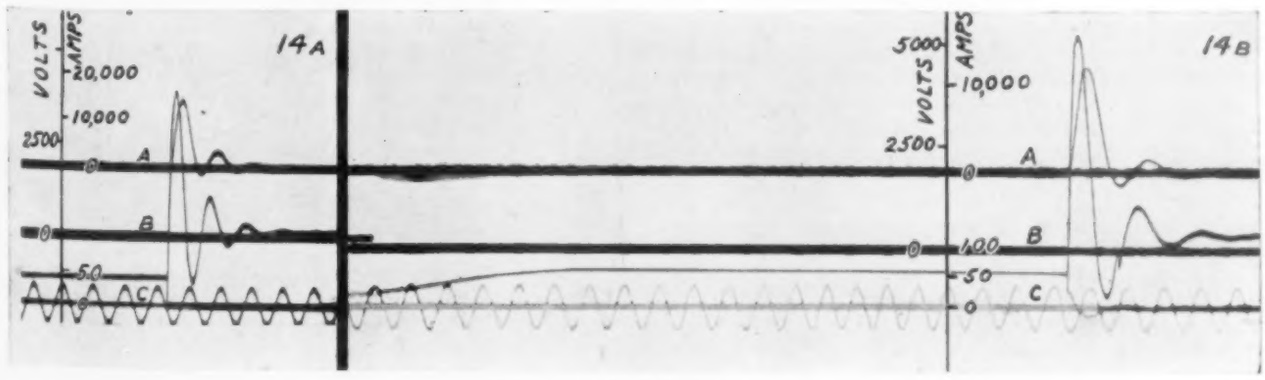



**Fig. 14—Tube Interruption**

(a) 4% air gap, long outside loop, turn ratio 890, 250-volt source, 60 amperes primary current, 27 mfd. capacitance
(b) 4% air gap, long outside loop, turn ratio 890, 112-volt source, 48 amperes primary current, 30 mfd. capacitance. The point corresponding to 4% air gap in Fig. 2 was obtained from this oscillogram

Table 2

| Set-up | *A* No Air Gap Short Loop | *B* 1.29% Air Gap Short Loop | *C* 0.7% Air Gap Short Loop | *D* 1.29% Air Gap Long Loop | *E* 1.29% Air Gap Long Loop | *F* 1.29% Air Gap Long Loop | *G* 1.29% Air Gap Long Loop | *H* 1.29% Air Gap Long Loop | *I* 0.7% Air Gap Long Loop |
|---|---|---|---|---|---|---|---|---|---|
| Turn ratio | 30 | 80 | 80 | 80 | 890 | 750 | 250 | 300 | 80 |
| $R_s$ ohms | 0.451 | 0.835 | 0.722 | 0.688 | 106 | 72 | 8.0 | 12.0 | 0.710 |
| $L_s$ henrys | 0.00182 | 0.00158 | 0.00158 | 0.00384 | 0.486 | 0.312 | 0.035 | 0.050 | 0.000384 |
| $R'_1$ ohms | 0.043 | 0.04 | 0.04 | 0.04 | 3.15 | 2.31 | 0.32 | 0.50 | 0.04 |
| $R_2$ microhms | 452 | 125 | 125 | 159 | 159 | 159 | 159 | 159 | 159 |
| $L_1$ henrys | 0.483 | 0.00875 | 0.0113 | 0.00875 | 1.08 | 0.737 | 0.0818 | 0.118 | 0.0113 |
| $L_{12}$ millihenrys | 16.1 | 0.109 | 0.142 | 0.109 | 1.21 | 0.982 | 0.327 | 0.394 | 0.142 |
| $L_2$ millihenrys | 0.540 | 0.00167 | 0.00206 | 0.00256 | 0.00244 | 0.00227 | 0.00227 | 0.00227 | 0.00268 |
| $L_{20}$ millihenrys | 0.000203 | 0.000302 | 0.000288 | 0.00107 | 0.00112 | 0.000962 | 0.000962 | 0.000962 | 0.000905 |

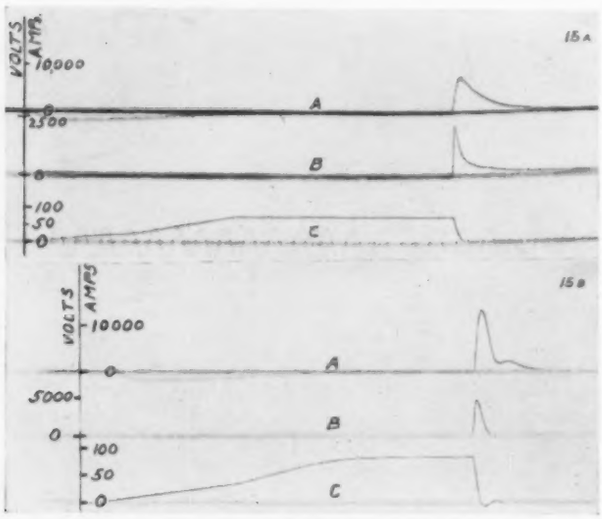



**Fig. 13—Tube Interruption, Effect of Resistance in Parallel with Tube ($R_s$ in Fig. 4)**

(a) Set-up *F*, $R_s$ A 46 ohms
(b) Set-up *F*, $R_s$ = 230 ohms
230-volt source, 80 amperes primary current, capacitance 17.4 mfd. These curves should be compared with Fig. 13 (*b*), which is the corresponding curve for $R_s = \infty$.

On all the oscillograms the trace marked *A* is the secondary or welding current, that marked *B* is the voltage across the switch or tube as the case may be, and that marked *C* the primary current.

Table 2 is a list of the various circuit constants for all the set-ups for which oscillograms are given.

Set-up *A* was a conventional transformer having a three-legged core with a 60-turn primary and a 2-turn secondary. All other set-ups were made on a three-legged core having air gaps between both ends of the legs and the connecting yokes. The air gap was varied by increasing the gap between the top of the legs and the upper yoke. Air gap is measured in per cent of the total length of the magnetic path. On this basis a 0.7% air gap corresponds to the top yoke in contact with the legs, and a 6% air gap corresponds to removing the yoke entirely.

Two lengths of the secondary loop, corresponding to the jaws and electrodes of an actual welding transformer, were used. The "short loop" was approximately a U-shaped piece of 3 inch x 1/8 inch copper 10 inches long and 5 inches wide. The "long loop" was similar except that it was 40 inches long.

Turn ratios were varied by using different primary coils. The secondary was always a single turn. For set-ups involving 80 and 890 turn primarys the secondary turn was wound on the outside of the primary. For other set-ups the primary coils were made in three sections and the secondary made of two loops in parallel sandwiched between the primary sections. This construction reduces the secondary leakage flux.

In the case of tube interruption the capacitance was usually in two places (see Fig. 4). However, since the internal resistance and inductance of the source were small, it was found that for most purposes the two capacitors could be considered as though they were both in parallel across the transformer.

## APPENDIX I

### CALCULATION OF WELDING CURRENTS

In this part of the paper a complete mathematical analysis of the behavior of electro-magnetic stored energy welding circuits will be given. First formulas will be developed for the various circuits in which all the resistances, inductances and capacitances are assumed to have constant values. These formulas turn out to be too complicated to have much practical value, so simplifying assumptions will be introduced and new simplified expressions derived. A method will then be introduced for adjusting the values of the inductances to account for the effects of saturation of the iron core of the transformer. The accuracy of resulting formulas will be tested by comparing calculated curves with oscillograms obtained experimentally.

The following symbols will be used (see Fig. 3):

$E$ = voltage of direct current source.
$R_1$ = $R'_1 + R_s$ = total primary resistance in ohms.
$R'_1$ = resistance of transformer primary and source in ohms.
$R_s$ = resistance across switch in ohms.
$R_2$ = total secondary resistance in ohms. This includes the resistance of the weld.
$L_1$ = total primary self-inductance in henrys.
$L_2$ = total secondary self-inductance in henrys.
$L_{12}$ = mutual inductance in henrys. The above symbols are the unsaturated values of inductance, that is, the values which should be used when the flux density in the core is low.
$L_{1s}$, $L_{2s}$, $L_{12s}$ = similar inductances under saturated conditions.
$L_2$ = leakage inductance of secondary and outside loop in henrys.
$k$ = saturation factor.
$R_e$ = effective value of resistance in ohms. This is the apparent resistance of the transformer measured with a. c. from the primary side, secondary short-circuited.

$X_s$ = effective value of reactance in ohms. This is the apparent reactance of the transformer measured from the primary side, secondary short-circuited.

$L_s = \frac{X_s}{\omega}$ = inductance corresponding to $X_s$.

$\omega = 2\pi f$.

$f$ = frequency of a. c. used for measurement.

$n$ = turn ratio of transformer.

$i_1(t)$ = primary current at time $t$.

$i_2(t)$ = secondary current at time $t$.

$v_s(t)$ = voltage across switch at time $t$.

Certain other symbols defined in terms of the above quantities will be introduced as needed.

*Derivation of Complete Formulas*

The following differential equations apply to the circuit of Fig. 3 after switch $S$ opens.

$$0 = V_c + R_1 i_1 + L_1 \frac{di_1}{dt} - L_{12} \frac{di_2}{dt} \tag{1}$$

$$0 = -L_{12} \frac{di_1}{dt} + R_2 i_2 + L_2 \frac{di_2}{dt} \tag{2}$$

$$i_1 = C \frac{dV_c}{dt} \tag{3}$$

These equations may be solved by the method of LaPlacian transforms and the following expressions found for the transforms of the primary and secondary currents:

$$I_1 = \frac{p^2[L_1L_2 - L_{12}^2]i_1(0) - V_c(0)[R_2 + pL_2] + pR_2[L_1 i_1(0) - L_{12} i_2(0)]}{(L_1L_2 - L_{12}^2)\{p^3 + 3C_2p^2 + 3C_1p + C_0\}} \tag{4}$$

$$I_2 = \frac{p^2[L_1L_2 - L_{12}^2]i_1(0) - V_c(0)[pL_{12}] + (pR_1 + \frac{1}{C})[L_2 i_2(0) - L_{12} i_1(0)]}{(L_1L_2 - L_{12}^2)\{p^3 + 3C_2p^2 + 3C_1p + C_0\}} \tag{5}$$

where:

$$C_2 = \frac{1}{3}\frac{R_1L_2 + R_2L_1}{L_1L_2 - L_{12}^2} \tag{6}$$

$$C_1 = \frac{1}{3}\frac{CR_1R_2 + L_2}{C(L_1L_2 - L_{12}^2)} \tag{7}$$

$$C_0 = \frac{R_2}{C(L_1L_2 - L_{12}^2)} \tag{8}$$

The actual currents may be found from these transforms by means of an expansion theorem.

We will now consider some special cases.

Case I. No capacitor, $S$ suddenly opened:

$C = 0$ $\qquad$ $V_c(0) = -E$

$R_s = \infty$ $\qquad$ $R_1 = \infty$

$i_1(0) = \frac{E}{R_1'}$ $\qquad$ $i_2(0) = 0$

This corresponds to sudden complete interruption of the primary current.

$$I_1 = 0$$

$$I_2 = \frac{L_2 E}{R_1'(L_2 p + R_2)} \tag{9}$$

The time function corresponding to this transform is:

$$i_2(t) = \frac{EL_{12}}{R_1'L_2} \varepsilon^{-\frac{R_2}{L_2}t} \tag{10}$$

Complete interruption of the circuit in this manner cannot occur as, if it did, an infinite voltage would appear across the switch.

Case II. No capacitor, $S$ suddenly opened:

We will therefore consider as Case II the sudden insertion of a resistance, $R_s$, into the circuit. In this case:

$C = 0$ $\qquad$ $R_1 = R_s + R_1'$

$i_1(0) = \frac{E}{R_1'}$ $\qquad$ $V_c(0) = -E$

$i_2(0) = 0$

In this case the transforms are:

$$I_1 = \frac{[p(L_1L_2 - L_{12}^2) + L_1R_2]\frac{E}{R_1'} + [pL_2 + R_2]\frac{E}{p}}{(L_1L_2 - L_{12}^2)(p^2 + \frac{R_1L_{12} + R_2L_1}{L_1L_2 - L_{12}^2}p + \frac{R_1R_2}{L_1L_2 - L_{12}^2})} \tag{11}$$

$$I_2 = \frac{EL_{12} - R_1L_{12}\frac{E}{R_1'}}{(L_1L_2 - L_{12}^2)(p^2 + \frac{R_1L_2 + R_2L_1}{L_1L_2 - L_{12}^2}p + \frac{R_1R_2}{L_1L_2 - L_{12}^2})} \tag{12}$$

The time functions corresponding to these transforms are:

$$i_1(t) = \frac{E}{R_1'} + \frac{ER_2a}{R_1R_1'd}\frac{\varepsilon^{-\alpha_1 t} - \varepsilon^{-\alpha_2 t}}{2} + \frac{ER_2}{RR_1'}\frac{\varepsilon^{-\alpha_1 t} + \varepsilon^{-\alpha_2 t}}{2} \tag{13}$$

$$i_2(t) = \frac{ER_2L_{12}}{R_1'd}\frac{\varepsilon^{-\alpha_1 t} - \varepsilon^{-\alpha_2 t}}{2} \tag{14}$$

$$v_s(t)_{max} = E\frac{R_s}{R_1'} \qquad v_s(t) = i_1R_s \tag{15}$$

where:

$$a = \frac{R_1L_2 - R_2L_1}{2} \tag{16}$$

$$b = \frac{R_1L_2 + R_2L_1}{2} \tag{17}$$

$$d = \sqrt{a^2 + R_1R_2L_{12}^2} \tag{18}$$

$$\alpha_1 = \frac{b - d}{L_1L_2 - L_{12}^2} \tag{19}$$

$$\alpha_2 = \frac{b + d}{L_1L_2 - L_{12}^2} \tag{20}$$

Case III. Successive insertion of resistance, no capacitor, other conditions same as Case II:

To compute currents when successive values of resistance are inserted in the circuit the calculation must be carried out using a different formula for each time interval during which a different resistance is in the circuit. These formulas are derived from transforms similar to those in Case II. The typical expression for $i_1(t)$ is:

$$i_1(t) = \frac{E}{R_1'} - \left\{\left[\frac{E}{R_1'} - i_1(0)\right]a - R_2L_{12}i_2(0)\right\}\frac{\varepsilon^{-\alpha_1 t} - \varepsilon^{-\alpha_2 t}}{2d} - \left[\frac{E}{R_1'} - i_1(0)\right]\frac{\varepsilon^{-\alpha_1 t} + \varepsilon^{-\alpha_2 t}}{2} \tag{21}$$

and for $i_2(t)$ is:

$$i_1(t) = \left\{\left[\frac{E}{R_1'} - i_1(0)\right] L_{12} R_1 + a\, i_2(0)\right\} \frac{\varepsilon^{-\alpha_1 t} - \varepsilon^{-\alpha_2 t}}{2d} + i_1(0)\frac{\varepsilon^{-\alpha_1 t} + \varepsilon^{-\alpha_2 t}}{2} \quad (22)$$

In both of these expressions $R_1$, $a$, $d$, $\alpha_1$ and $\alpha_2$ must be calculated for the value of $R_s$ during the interval, and $i_1(0)$ and $i_2(0)$ are the values of $i_1(t)$ and $i_2(t)$ at the beginning of the interval. During each interval $t$ should be taken equal zero at the beginning of the interval. The voltage increase at the beginning of each interval is the product of the increase in resistance and the current flowing at the beginning of the interval.

Case IV. Capacitor present, $S$ suddenly opened:

$$R_s = \infty \qquad R_1 = R_1'$$
$$i_1(0) = \frac{E}{R_1'} \qquad v_c(0) = -E$$
$$i_2(0) = 0$$

$$I_1 = \frac{E}{R_1'}\left[\frac{p^2(L_1L_2 - L_{12}^2) + p(R_1L_2 + R_2L_1) + R_2}{(L_1L_2 - L_{12}^2)\{p^3 + 3C_2p^2 + 3C_1p + C_0\}}\right] \quad (23)$$

$$I_2 = \frac{E}{R_1'}\left[\frac{p^2(L_1L_2 - L_{12}^2) - \frac{R_1L_{12}}{C}}{(L_1L_2 - L_{12}^2)\{p^3 + 3C_2p^2 + 3C_1p + C_1\}}\right] \quad (24)$$

The time functions corresponding to these transforms will be of a different nature according as the roots of the cubic equation in the denominator are all real or one real and two complex. Let us consider the latter case first.

Case IV*a*. Roots:

$$p_1 = -\alpha_1$$
$$p_2 = -\alpha_2 + j\omega_2$$
$$p_3 = -\alpha_2 - j\omega_2$$

$$I_1 = \frac{E}{R_1'}\left[\frac{p^2(L_1L_2 - L_{12}^2) + p(R_1L_2 + R_2L_1) + R_2}{(L_1L_2 - L_{12}^2)(p + \alpha_1)[(p + \alpha_2)^2 + \omega_2^2]}\right] \quad (25)$$

$$I_2 = \frac{E}{R_1'}\left[\frac{p^2(L_1L_2 - L_{12}^2) - \frac{R_1L_{12}}{C}}{(L_1L_2 - L_{12}^2)(p + \alpha_1)[(p + \alpha_2)^2 + \omega_2^2]}\right] \quad (26)$$

The time function corresponding to $I_1$ is:

$$i_1(t) = \frac{E}{R_1'}\left\{\varepsilon^{-\alpha_1 t}\left[\cos\omega_2 t + \frac{\alpha_2}{\omega_2}\sin\omega_2 t\right]\right.$$
$$\left. - \frac{\frac{R_1R_2}{L_1L_2L_{12}} - 2\alpha_2\alpha_1}{(\alpha_1 - \alpha_2)^2 + \omega_2^2}\left[-\varepsilon^{-\alpha_1 t} + \varepsilon^{-\alpha_2 t}\left(\cos\omega_2 t + \frac{2\alpha_2}{\omega_2}\sin\omega_2 t\right)\right]\right\} \quad (27)$$

$$i_2(t) = \frac{E}{R_1'C}\left\{\frac{L_{12}}{(L_1L_2 - L_{12}^2)[(\alpha_2 - \alpha_1)^2 + \omega_2^2]}\left[-\varepsilon^{-\alpha_1 t} + \varepsilon^{-\alpha_2 t}\left(\cos\omega_2 t + \frac{\alpha_2 - \alpha_1}{\omega_2}\sin\omega_2 t\right)\right]\right\} \quad (28)$$

$$v_c(t) = E + \frac{E}{R_1'C}\left\{\frac{\varepsilon^{-\alpha_1 t}}{\omega_2}\frac{\omega_2^2 + \alpha_1^2}{\alpha_1^2 + \omega_2^2}\sin\omega_2 t - 2\alpha_2\cos\omega_2 t\right. \quad (29)$$
$$\left. - \frac{\frac{R_1R_2}{L_1L_2 - L_{12}^2} - 2\alpha_1\alpha_2}{(\alpha_1 - \alpha_2)^2 + \omega_2^2}\left[\frac{\varepsilon^{-\alpha_1 t}}{\alpha_1} + \varepsilon^{-\alpha_2 t}\left(\frac{(\alpha_1 - 2\alpha_2)\cos\omega_2 t + \frac{\omega_2^2 - \alpha_2^2 - \alpha_1\alpha_2}{\omega_2}\sin\omega_2 t}{\alpha_2^2 + \omega_2^2}\right)\right]\right\}$$

If $C_1 > C_2^2$ and $C_0 > C_2^3$ the roots may be conveniently found as:

$$\alpha_1 = \frac{C_0 - C_2^3}{\omega_2^2} \quad (30)$$

$$\alpha_2 = \frac{3}{2}C_2 - \frac{1}{2}\alpha_1 \quad (31)$$

$$\omega_2^2 = 3(C_1 - C_2^2) \quad (32)$$

Case IV*b*. Roots:

$$p_1 = -\alpha_1$$
$$p_2 = -\alpha_2$$
$$p_3 = -\alpha_3$$

The transforms will be the same as Case IV*c* except that the cubic in the denominators will be:

$$(p + \alpha_1)(p + \alpha_2)(p + \alpha_3)$$

The time functions will then be:

$$i_1 = \frac{E}{R_1'(L_1L_2 - L_{12}^2)}\left\{\left[\frac{\alpha_1^2(L_1L_2 - L_{12}^2) - \alpha_1(R_1L_2 + R_2L_1) + R_2}{(\alpha_2 - \alpha_1)(\alpha_3 - \alpha_1)}\right]\varepsilon^{-\alpha_1 t}\right.$$
$$+ \left[\frac{\alpha_2^2(L_1L_2 - L_{12}^2) - 2(R_1L_2 + R_2L_1) + R_2}{(\alpha_1 - \alpha_2)(\alpha_3 - \alpha_2)}\right]\varepsilon^{-\alpha_2 t}$$
$$\left. + \left[\frac{\alpha_3^2(L_1L_2 - L_{12}^2) - \alpha_2(R_1L_2 + R_2L_1) + R_2}{(\alpha_1 - \alpha_3)(\alpha_2 - \alpha_3)}\right]\varepsilon^{-\alpha_3 t}\right\} \quad (33)$$

$$i_2 = \frac{E}{R_1'(L_1L_2 - L_{12}^2)}\left\{\left[\frac{\alpha_1^2(L_1L_2 - L_{12}^2) - \frac{R_1L_{12}}{C}}{(\alpha_2 - \alpha_1)(\alpha_3 - \alpha_1)}\right]\varepsilon^{-\alpha_1 t}\right.$$
$$+ \left[\frac{\alpha_2^2(L_1L_2 - L_{12}^2) - \frac{R_1L_{12}}{C}}{(\alpha_1 - \alpha_2)(\alpha_3 - \alpha_2)}\right]\varepsilon^{-\alpha_2 t}$$
$$\left. + \left[\frac{\alpha_3^2(L_1L_2 - L_{12}^2) - \frac{R_1L_{12}}{C}}{(\alpha_1 - \alpha_3)(\alpha_2 - \alpha_3)}\right]\varepsilon^{-\alpha_3 t}\right\} \quad (34)$$

*Simplification of Formulas*

With the exception of Case I the preceding formulas are too complicated to be of much practical value, so that it is desirable to simplify them. To do this note that approximately:

$$R_e = R_1' + \frac{L_1}{L_2}R_2 \quad (35)$$

$$L_e = L_1 - \frac{L_{12}^2}{L_2} \quad (36)$$

$$i_1(0) = \frac{E}{R_1'} \quad (37)$$

= primary current when $S$ opens

If, in addition, $R_s$ is much greater than $L_s$, say, $R_s > 1000L_s$, then the secondary current for Case II becomes:

$$i_2 = i_1(0)\frac{L_{12}R_s(\varepsilon^{-\alpha_1 t} - \varepsilon^{-\alpha_2 t})}{L_2(R_e + R_s)\sqrt{1 - 4\frac{\alpha_2}{\alpha_1}}} \quad (38)$$

where:

$$\alpha_1 = \frac{R_s(R_1' + R_2)}{L_2(R_e + R_s)} \quad (39)$$

$$\alpha_2 = \frac{R_e + R_s}{L_e} \quad (40)$$

Similarly if we assume that:

$$C_2^2 \ll C_0$$

$$C_2^2 \ll C_1$$

$$(\alpha_2 - \alpha_1) \ll \omega_2$$

equation (28) becomes:

$$i_s(t) = i_s(0)\frac{L_{12}}{L_2}\left[\epsilon^{-\alpha_1 t} - \epsilon^{-\alpha_2 t}\cos \omega_2 t\right] \quad (41)$$

and (29) becomes:

$$v_s(t) = E + \frac{i_s(0)}{C\omega_2}\epsilon^{-\alpha_2 t}\sin \omega_2 t \quad (42)$$

where:

$$\alpha_1 = \frac{R_2}{L_2} \quad (43)$$

$$\alpha_2 = \frac{R_e}{2L_e} - \frac{R_2}{2L_2} \text{ or } \frac{R_e}{2L_e} \quad (44)$$

$$\omega_2 = \frac{1}{\sqrt{CL_e}} \quad (45)$$

If equation (44) is derived from (31) the first value of $\alpha_2$ is obtained. However, equations (44) and (43) may also be derived approximately as the damping constant and frequency obtained when a voltage is applied to a series circuit made up of a capacitor in series with an inductor having the equivalent resistance and inductance of the transformer. The latter method gives the second value for $\alpha_2$. Since both are approximate, the true value is probably in between. Experiment shows that $\alpha_2 = R_e/2L_e$ is closer to being correct, and that value was used in the curves plotted in this paper. Figures 7, 9 and 13*d* show curves plotted from equations 10, 38, 41 and 42 compared with oscillograms determined experimentally.

*Adjusting Inductance Values for Saturation*

The constants $L_1$, $L_2$ and $L_{12}$ used in the preceding expression are in reality not constants but vary with the flux in the iron core of the transformer and in consequence vary with the current in the primary. Let the subscript $s$ be used to signify the "saturated" value of any inductance.

Let us make the following assumptions:

(*a*) Primary leakage reactance is negligible.
(*b*) Secondary leakage reactance is a constant independent of saturation.
(*c*) The equivalent resistance and inductance $R_e$ and $L_e$ are independent of saturation.

Based on these assumptions we may write:

$$L_{1s} = KL_1 \quad (46)$$

$$L_{2s} = L_{20} + K\frac{L_1}{n^2} \quad (47)$$

$$L_{12s} = K\frac{L_1}{n} \quad (48)$$

where $k$ is a constant less than unity. $k$ can be determined as follows from a magnetization curve of the iron core (see Fig. 5). Draw a line $OB$ corresponding to a primary magnetizing force of $OC$ ampere-turns. Draw a line $OA$ tangent to the lower part of the magnetization curve. Then

$$k = \frac{\text{slope of } OB}{\text{slope of } OA}$$

This value of $k$ corresponds to a magnetization of $OC$ ampere turns. There may be some question as to why the slope of $OB$ was used instead of the tangent at the point $B$. However, the value of inductance to be used should be some kind of an average corresponding to that of the tangent to the curve when $i_1 = 0$ and when $i_1$ equals its maximum value. The slope of $OB$ fulfils this condition, and calculations based on the value of $k$ so obtained agree well with experimental values. $L_1$ can be determined from an open circuit test of the transformer at a low value of magnetization. $L_{20}$ can be determined from a short circuit test as follows:

$$L_e = \frac{X_e}{2\pi f} = L_1 - \frac{L_{12}^2}{L_2} \quad (36)$$

where $X_e$ is short circuit reactance of the transformer at a frequency $f$.

From (47) when $k = 1$

$$L_{20} = \frac{L_e L_1}{n^2(L_1 - L_e)} \quad (49)$$

$$L_{2s} = \frac{L_e L_1}{n^2(L_1 - L_e)} + \frac{KL_1}{n^2} \quad (50)$$

$$\frac{L_{12s}}{L_{2s}} = \frac{n}{1 + \frac{L_e}{K(L_1 - L_e)}} \quad (51)$$

Figure 6 shows the variation of peak value of secondary current with primary current for a typical welding transformer. The solid line was calculated by obtaining the maximum values of current as given by equation (41) using inductances calculated from (50) and (51). The circles are experimentally determined points.

# Repairing a Pulp-Beater Drum

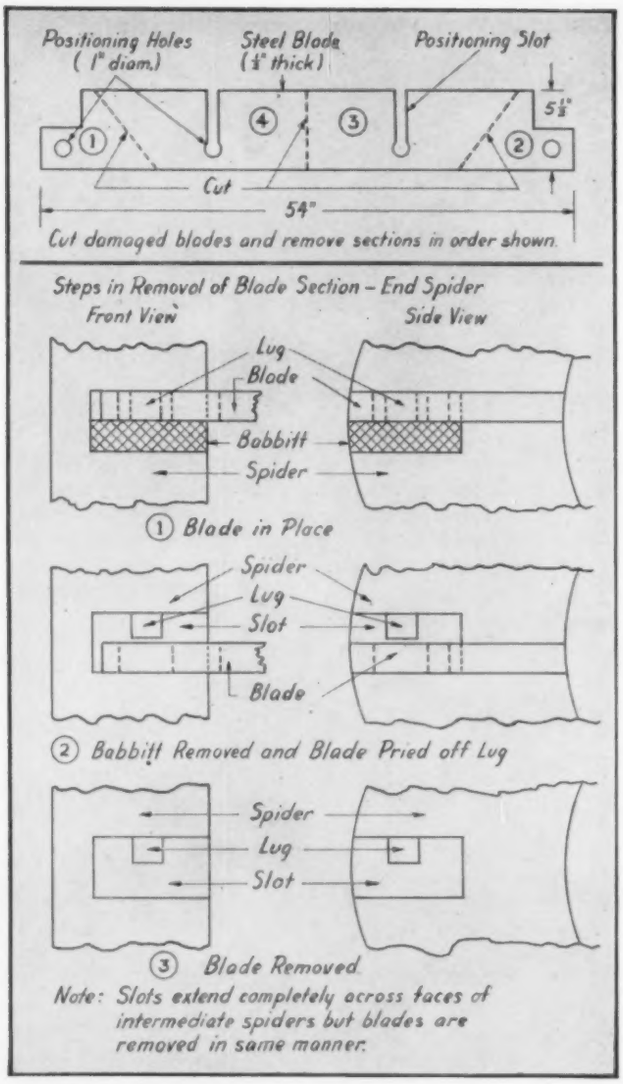
By H. B. GILSON*

IN THE maintenance of pulp-beater drums, replacement of broken blades can be considerably facilitated and speeded by use of the oxyacetylene flame. By following the procedures outlined here, the maintenance department of one paper mill now performs this particular operation in approximately half the time previously required. In addition to the usual economies resulting from a speedier repair, the high degree of control provided by the improved method almost completely eliminates the possibility of damage to the cast-iron spiders which support the blades, and permits the necessary repairs to be made without dismantling the machine.

* The Linde Air Products Co., Milwaukee, Wis.

## CONSTRUCTION OF DRUM

The beater drums at this mill are each constructed of four equally spaced cast-iron spiders measuring 64 inches




**Damaged Blades Are Cut and Removed in Four Sections by Melting and Scraping Out the Babbitt and Then Prying Them Off the Lugs of the Cast-Iron Spiders**

in diameter. Each drum is equipped with 66 steel blades ½ inch thick, 5½ inches wide and 54 inches long. As shown in the sketch, slots in the blades fit over lugs on the outer rims of the spiders and the blades are secured in place by babbitt of a high-antimony composition. Breakage of blade sections, caused by striking stones, pieces of iron or other foreign objects during operation of the beater, unbalances the drum and the efficiency of the unit is seriously affected. When this occurs, the broken blades must be removed and replaced with new ones.

### BLADE REMOVAL

As the first step in their removal, damaged blades are each cut into four parts with an oxyacetylene cutting blowpipe. As shown in the sketch, the two end cuts extend across the blade at an angle of approximately 45° while the third cut is located squarely across the center. All cuts are made midway between adjacent spiders.

When cutting is completed, the flame of a welding blowpipe is applied on the underside of the blade to the babbitt deposit which locks the blade to the lug and rim of the spider. Since the heated babbitt becomes soft but will not run, it is dug out of the spider slot with the end of a steel bar. A number of these bars are used. As one becomes too hot to handle, the operator sets it aside in a pail of water for cooling and takes up another.

Heat, which remains in the rim of the spider after the melted babbitt is scraped out of the slot, facilitates the prying of the blade section off the lug and subsequent withdrawal of the part from the slot. Heating and melting of the babbitt is confined to a single spider until all blade sections are removed. Operating in this manner permits more efficient distribution of the heat than would be possble if the operator were to attempt removing an entire blade. The latter procedure, of course, would necessitate heating all four spiders and, unless extreme care were taken, might result in cracking of the cast iron.

Blade sections are removed in the order shown in the sketch, starting at one end of the drum. When all have been removed from this spider, the operator carries on the second stage of the work at the opposite end of the drum. The two center sections are then removed, progressively working one spider at a time.

# Arc-Welded Steel Found Most Economical in Reconstructing Damaged Bridge Pier*

THE upper West 3rd Street bridge over Cuyahoga River was built in 1883 by The C. H. Strong Company and The King Bridge and Manufacturing Company.

The original bridge consisted of a substructure of stone masonry and a superstructure of iron. The original substructure cost $17,973.99. The original superstructure cost $13,991.75.

The total over-all length of the bridge is 180 feet, the north approach is 44 feet in length and the south approach is 66 feet in length. The width of the roadway between curbs is 18 feet with a 4 foot 7 inch sidewalk on the outside of each truss. The bridge has a minimum clearance over the water of 16 feet 6 inches and a floor depth of 2 feet 4 inches. The bridge provides a clear channel of 67 feet on either side of the center pier.

The upper West 3rd Street bridge is so located that continuous operation is important. It is the principal means of access from the east side of the city to the 900-ton City Refuse Incinerator, and it also serves as a major link with the downtown area. Since many industrial plants in the Cuyahoga River Valley are dependent upon river traffic, it is essential that the channel be kept clear at all times. It is therefore important that any repair or replacement requiring an interruption of either street or river traffic should be as infrequent and occupy as short a time as possible.

A tub and two loaded barges passed through the recently dredged north channel. In passing, a corner of the last barge struck the side of the north pier and caused it to slide into the river.

The failure of this pier prevented the bridge from being

* Data and illustrations from award study submitted to The James F. Lincoln Arc Welding Foundation by John M. Heffelfinger and H. T. Borton, bridge engineer and assistant bridge engineer, respectively, City of Cleveland, Ohio. In its $200,000 Industrial Progress Award Program, which closes June 1, 1942, the Foundation is offering 458 awards from $100 to $13,700, for reports of advances and improvements made by application of arc welding in design, manufacture, fabrication, construction and maintenance.

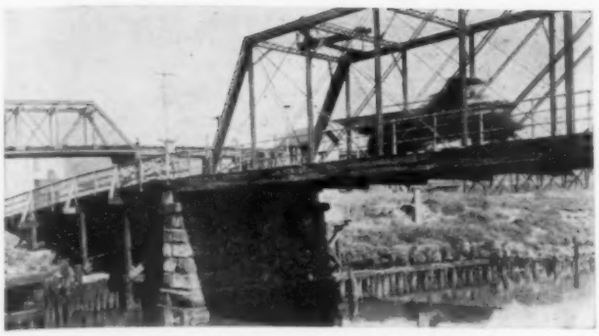


Fig. 1—Stone Pier Which Was Damaged, Necessitating Reconstruction

used for vehicular traffic and closed the north channel of the river to navigation. The bridge, however, could be swung to permit river traffic in the south channel and could be closed sufficiently to allow pedestrians to cross it.

*Designs for Replacement.*—The city started the preparation of plans with three questions in mind: first, what type of construction should be used; second, what would be the estimated cost of replacement; and third, what time would be required to rebuild the pier and place the bridge in operation.

Four types of construction were investigated: first, stone masonry; second, reinforced concrete; third, structural steel; and fourth, timber.

*Estimated Cost of Replacement.*—In preparing the estimates for deciding which of the various types of construction were the most economical it was necessary to investigate three different items of cost: first, the initial cost; second, the maintenance charges; third, annual cost based on a predetermined life of the structure of fifteen years.

Since the bridge is now 57 years old, it is reasonable to expect that replacement will be necessary within the next fifteen years. Any pier construction made now may not be adaptable to a new bridge since it is hardly likely that a center swing bridge will be built to replace the one now in use. It therefore seems fair to compare the costs of the different types of structures on the basis of a fifteen-year period of life. Since the period will be the same for any type of structure selected, the annual cost as reflected in interest and amortization will be proportional to the initial cost and for the purpose of comparison may be assumed as $^1/_{15}$ the annual cost plus the estimated maintenance requirements. The following estimates are based on the corresponding plans accompanying these estimates.

The following tables shows the annual cost for each type of construction:

| | Initial Cost | $^1/_{15}$ of Initial Cost | Annual Maintenance | Total Annual Cost |
|---|---|---|---|---|
| *A.* Stone | $16,000 | $1067 | $ ..... | $1067 |
| *B.* Concrete | 15,000 | 1000 | ..... | 1000 |
| *C.* Steel (welded) | 11,000 | 733 | 10.00 | 743 |
| (riveted) | 13,700 | 915 | 15.00 | 930 |
| *D.* Timber | 9,500 | 633 | 350.00 | 983 |

*Estimated Time for Construction.*—Since the closing of the bridge seriously inconvenienced highway traffic and the presence of equipment in the river for the replacement of the pier hindered the movement of the bridge for river traffic, time was an essential element in the replacement program. The period of time required to construct the various types of pier was estimated in the following table:

| | |
|---|---|
| Stone | 12 weeks |
| Concrete | 8 weeks |
| Steel (welded) | 5 weeks |
| (riveted) | 8 weeks |
| Wood | 6 weeks |

After all the facts and figures were completed, it was decided to reconstruct the pier using the structural steel type of design.

*Construction of New Pier.*—The order to start work was given on May 25th, and two days later a scow, or barge, carrying the pile-driving equipment arrived on the job with the structural steel piles and by the end of the day two piles were driven. The equipment on the scow handled the materials as well as driving them. The fourteen structural steel piles were driven in four days, but the equipment remained on the job to drive the wood piles for fenders after the structural steel sections were placed.

As rapidly as the piles were driven they were pulled into line (where necessary), cut off to a predetermined elevation and the horizontal channels placed and tack welded. These channels were ordered in lengths of 30 feet and no cutting was required to frame them into the structure. The next sections placed were the 12-inch horizontal members between the piles. The spaces between the piles were measured and the 12-inch section flame cut from stock lengths, swung into place by a "gin" pole rig and held until they were tack welded. The members were light and easily handled and the tack welding took less time than usually required to place it with drift pins and bolts.

After all the horizontal members were placed and tack welded as described above, wood templets, using $^7/_8$-inch pine board, were made for the diagonal members. After cutting, the board was fitted to see that the proper measurements and angles were made and then placed on the

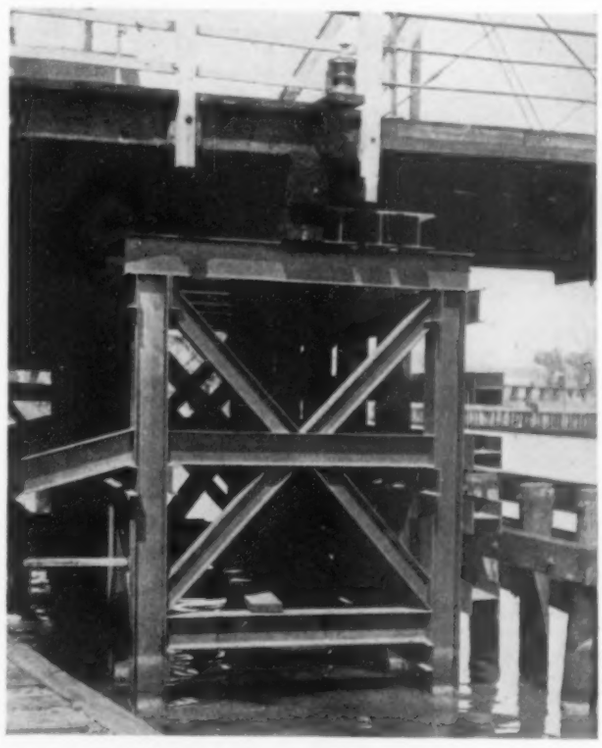


Fig. 2—Arc-Welded Steel Pier Erected at Saving of $62 per Ton

steel member and the same flame cut. This took very little time and insured a good fit. The member was then swung into place and tack welded. The wood templets were cut, fitted and the work laid out for the next member while the previous one was being tack welded in the structure. The templets were re-used for duplicate sections and recut for shorter members. Only a few erection bolts, but no drift pins, clamps or other devices were used on the job to hold the members in place for fabrication or welding.

Final welds were made after all the steel was in place, except where the completed welds had to be made before later members could be placed or where making the final weld interfered with or delayed the placing of the approach members.

Weld beads were laid in almost every possible position, although vertical and flat welds were favored wherever possible.

*Amount of Materials and Welding.*—The total amount of steel placed is as follows:

| | |
|---|---|
| Structural steel piling | 47,329 lb. |
| Structural steel framing | 46,818 lb. |
| Total | 94,147 lb. |

450 lineal feet of welding was required.

*Actual Cost Figures.*—Figures were supplied by the contractor showing the cost of the work.

| | |
|---|---|
| Total Cost (per ton) of Erection—Welded | |
| Labor, erection and welding | $ 69.88 |
| Materials | 68.23 |
| Cost per ton | $138.11 |
| Cost (per ton) of Erection—Riveted | |
| Cost including drilling, fitting and riveting, 50¢ per rivet | $1800.00 |
| Cutting members in field | 273.01 |
| Erection of members | 1024.20 |
| | $3097.21 |
| $\frac{3097.21}{27.5}$ | = 112.62 |
| Cost of Materials | $ 68.23 |
| Gussets and additional materials, (20% of above) | 13.65 |
| Extra tools, etc., for riveting | 5.50 |
| Total estimated cost per ton | $200.00 |

From the above figures it can be seen that the approximate saving realized on this job is $200.00 − $138.00 = $62.00 per ton or a total of 27.5 × $62.00 = $1905.00.

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## MODERN PRACTICE IN BAKERY MAINTENANCE FEATURES ELECTRIC ARC WELDING

By A. F. DAVIS*

Bakery maintenance, consisting of everything from repair of a bar in a dough mixer to building the framework of a cake rack, is accomplished with simplicity and economy by arc welding.

According to users, the electric arc is the all-purpose maintenance tool, effective in repair of broken and worn parts, in fabrication of miscellaneous equipment and replacements, also in erecting piping, duct work and structures.

A typical example of this varied use of arc welding in maintenance is Schultz's Bakery of Chicago, Illinois. This company employs arc welding with important economies in time and cost. Seldom are pieces of equipment scrapped and replaced because of breakage or wear. Instead of purchasing costly replacements, the maintenance department welds in a new plate to mend the break or applies new metal to restore the wearing surface. The same is true of structural work: the maintenance department does the job itself, erecting its own new structures and strengthening or altering existing ones as the occasion requires. The result of this versatility and flexibility is an annual saving of many thousands of dollars. In addition to direct maintenance cost savings, there is the added important advantage of avoiding excessive outage time of primary equipment. With arc welding, repairs are accomplished speedily instead of waiting for replacements while production is at a standstill.

Typical examples of arc welding in bakery maintenance are shown in the accompanying illustrations.

Figure 1 is a photo of the welding and machine shop of the bakery. On the left is shown an ammonia regenerator in the course of construction; on the right, an oil trap for an ammonia system in the course of construction. The various parts of these two jobs are illustrated. The heads for the drums are purchased. The remainder of the material is mostly pipe of 12-inch and 10-inch sizes. Estimated savings over purchase of equipment on the outside are about 50%.

* Vice-President, The Lincoln Electric Co., Cleveland, O.

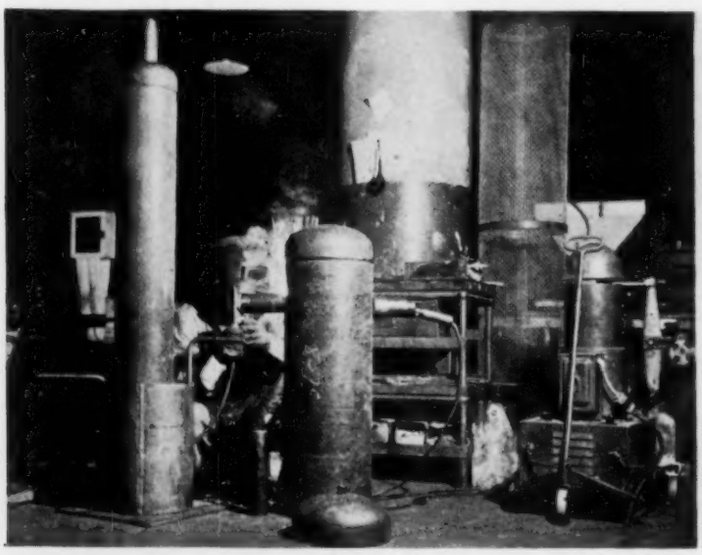


Fig. 1—The Welding and Machine Shop of Schultz's Bakery of Chicago. (Left) Building Ammonia Regenerator; (Right) Fabricating an Oil Trap by Arc Welding

Fig. 2—Arc Welding a Broken Cast-Iron Lever for a Cake Scaler

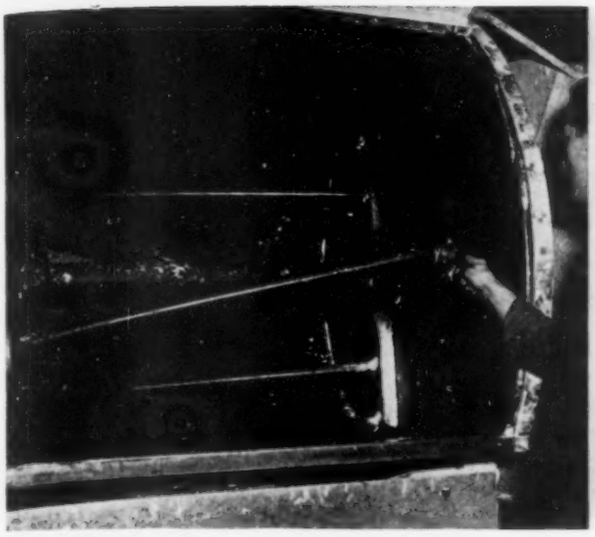


Fig. 3—Arc-Welded Mixing Bar in Dough Mixer

Fig. 4—Arc-Welded Guide on Cake Conveyor

Fig. 5—New Steel Plate Arc Welded to Dough Mixer

Fig. 6—Cake Rack of All-Welded Construction

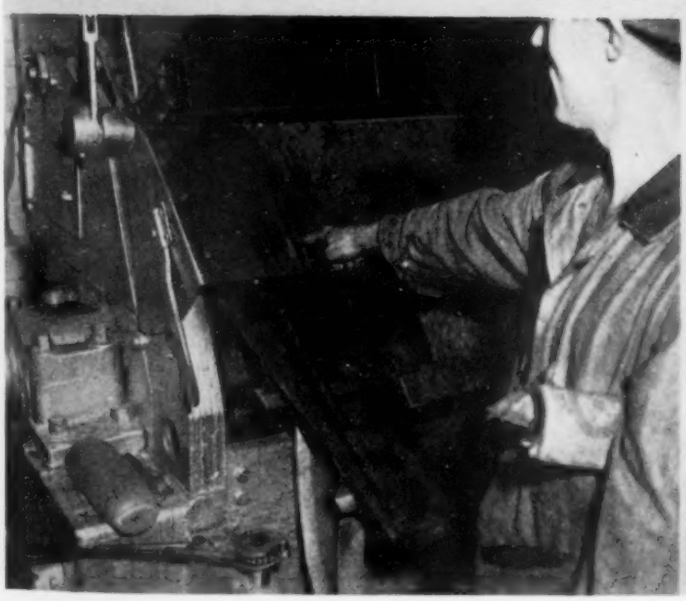


Fig. 7—Cracked Oven Door Repaired by Arc Welding

Fig. 8—Arc-Welded Repair of Copper Mixing Bowl

In Fig. 2 the arc welder is repairing a cast-iron lever for a cake scaler.

When the mixing bars of the dough mixers become loose, they are welded securely in place (see Fig. 3). The blades are 2-inch piping.

Figure 4 shows a roller bracket for a cake conveyor. The guide on the side of this bracket was welded on by the maintenance department.

The outside walls of the dough mixers (see Fig. 5) are replaced when they become worn and loose. New steel plate is bent to shape and welded into place with fillet welds all around the sides. This plate is $^1/_4$ inch thick and is welded with $^3/_{16}$-inch electrode.

Figure 6 shows a cake rack of all-welded steel construction. The framework is built from angle iron, plate and flat bar stock. The reinforcing bar shown was added to this particular rack.

A typical repair job is illustrated in Fig. 7. This bread-oven door cracked in service was welded by the electric arc.

Figure 8 shows the bottom of a copper mixing bowl. When these mixing bowls become thin on the bottom due to stirring and rubbing on the floor, they are built up with an electrode made expressly for arc welding copper.

In Fig. 9 can be seen a welded motor base in a dough mixer. This base was fabricated from standard channels by arc welding.

The dough buggies shown in Fig. 10 were built by the maintenance department using $^1/_4$-inch steel plate and 2-inch pipe for the top edges. The result is a very sturdy, light-weight construction which is devoid of corners and pockets where dough can collect and thereby make it difficult to keep them clean.

The vaporizer system which supplies steam vapor to the bread ovens to prevent excessive drying out is shown in Fig. 11. These vessels and some of the piping are of arc-welded construction, built by the maintenance department.

Smoke pipes from bread ovens built by welding from 11-gage black iron can be seen in Fig. 12. All welding was done by the maintenance department.

Fig. 9—Arc-Welded Motor Base of Dough Mixer

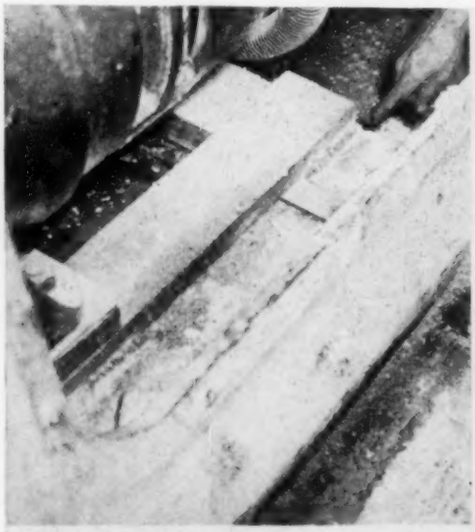


Fig. 10—Dough Buggies Built by Arc Welding

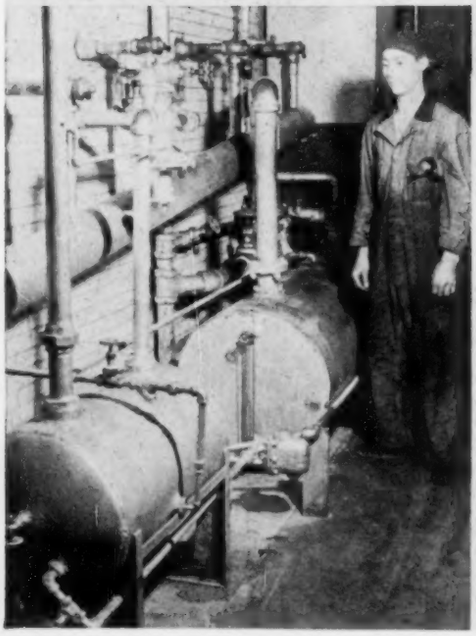


Fig. 11—Arc-Welded Vessels and Piping in Vaporizer System

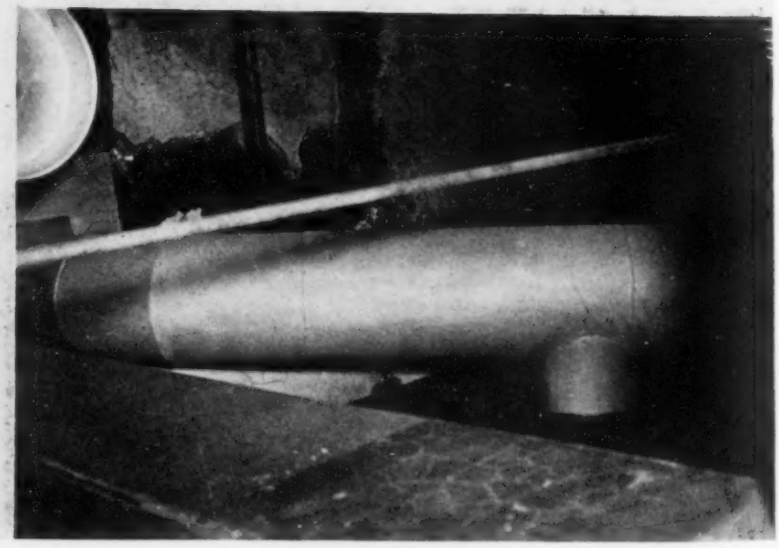


Fig. 12—Arc-Welded Smoke Pipes

# RESISTANCE SPOT WELDS

By J. W. MEADOWCROFT*

IN ORDER to make a dependable spot weld, it is necessary to know the optimum conditions, to have apparatus adjusted to these optimum conditions, and to be able to maintain these conditions within a reasonably narrow range of variation. If there is any doubt as to the reasonable consistency of any of the important conditions, some means should be provided to indicate to the operator that undesirable changes have taken place and that there is serious doubt as to the soundness of the weld just made.

Long experience shows that these are the only conditions under which one can be reasonably sure of a uniformly good weld.

Unfortunately, there is no satisfactory non-destructive test for spot welding. Moreover, in spite of some opinions to the contrary, the external appearance of the finished weld is not a safe guide unless it is an extremely bad weld. The only simple practical test is the chisel test which is not only not accurate from the quantitative point of view but distorts the parts to an undesirable degree and takes at least as much time as the making of the weld.

It is, thus, peculiarly desirable in the case of spot welds to be sure that each weld is a substantially perfect one and able to stand up under service conditions including the maximum stress assigned to it. Such assurance can come only with the accurate controls and checks above outlined. Without them the strength of the several welds of a given series made apparently under similar conditions is almost certain to vary widely.

Although the total list of variables affecting the strength of a spot weld is a very long one, the major variables are listed below:

1. Current.
2. Time of current flow.
3. Pressure on the electrodes.
4. Material of the electrodes.
5. The shape of the electrodes.

The optimum values of these several variables will vary with (*a*) the physical and metallurgical characteristics of the metal employed, (*b*) the thickness of the metal, (*c*) the apparatus available. That is, the capacity of the apparatus may not be sufficient to employ the most desirable combination of variables although the results may be fairly satisfactory.

In order to consider intelligently the influence of the first three of these major variables, start with the fact that the heat delivered to the weld zone (measured in joules) is equal to $I^2rt$, where $I$ is the r.m.s. value of the current (amperes) during the time of current flow, $t$ (seconds) and $r$ the resistance of the weld zone (ohms). This heat must be sufficient to fuse enough metal at the interfaces to make a sound weld.

It is obvious from the formula that there are many combinations of $I$ and $t$ which would yield the same total heat but this does not tell the whole story since all of the heat does not stay put. Some of it is conducted away through the base metal, some of it is dissipated from the hot surfaces of the base metal and a frequently more important part is carried away by the electrodes with their large thermal conductivity. In other words, the heat loss is approximately proportional to the time, $t$, and it takes more total heat to make a weld slowly than rapidly.

It is also obvious that the $I^2t$ necessary will be inversely proportional to resistance ($r$). The part of the resistance which contributes the welding heat is the interface contact resistance between the sheets and the body resistance of the sheets themselves.

As it is impossible to discuss intelligently the effect of the several variables without a clear and fairly quantitative picture of the phenomena which take place during the welding cycle, let us consider these in order of time.

At the start, the localized interface contact resistance causes a development at this interface of much more heat than in any other part of the zone. Fusion begins at the center of this interface and spreads rapidly, although the rate of heat generation is still a maximum in the same zone, since after fusion the resistivity of the hot metal is often several times as much as that of the cool metal. Thus, the original high contact resistance is replaced by a thin layer of very hot or molten metal of very high resistivity.

It is thus obvious that the total heat as well as its distribution will vary with the thickness of the sheets, with the normal resistivity of the metal and with the contact resistance, which in turn will depend upon the nature of the material, the condition of the surfaces and the electrode pressure. Moreover, since the contact resistance is roughly inversely proportional to the electrode pressure, the current required will obviously increase with that pressure.

## INFLUENCE OF THE PHYSICAL AND METALLURGICAL PROPERTIES OF THE METAL BEING WELDED

Although space does not permit a reasonably complete analysis of the phenomena involved, it may be of interest to note the effect of a few of the major variables.

(*a*) *Electrical and Thermal Conductivity.*—These are considered together since they are roughly proportional to each other. High conductivity as of copper or aluminum means less body resistance and less heat developed thereby for a given current. It also means a higher rate of heat dissipation. Most of these high conductivity materials are softer and yield a lower contact resistance unless the surface is covered by a considerable oxide film of high resistance as in the case of aluminum.

It is, thus, obvious that the high-conductivity materials demand a higher current as well as a shorter duration of current flow since the heat must be developed rapidly enough to avoid serious loss by conduction.

(*b*) *Specific Heat, Specific Gravity and Melting Point.*—The combination of these determines the amount of heat necessary to fuse a given volume of the metal. For example, the amount required in the case of aluminum,

* Assistant Works Manager, Edward G. Budd Mfg. Co., Philadelphia Penna.

other things being equal, is less than 30% of that required for steel.

(*c*) *Plastic Temperature Range.*—The lower this range, the more critical will be the necessity for accurate control of the welding factors and, in general, the greater the difficulty of making a good weld. Aluminum is again a good example of this limitation.

(*d*) *Rate of Cooling and Its Influence on the Microstructure of the Weld Zone as Well as Upon Residual Stresses.*—In the vast majority of spot welds, particularly in thin sheets, the rate of heat delivery as well as the rate of cooling is very rapid. In most carbon or low-alloy steels, the result of this rapid rate of cooling is a hard, brittle structure which may have full strength under static stress but is weak under impact or fatigue stresses. This weakness is accentuated by the fact that a higher rate of cooling also develops higher residual stresses. If the weld zone could be forged or peened sufficiently during the cooling period, both of these troubles would be largely eliminated. Unfortunately, the static electrode pressure necessary to do this forging after the metal has cooled below the plastic range is not feasible with any except very soft materials and even there has only a small effect.

In a rough way the above remarks apply to the more common aluminum alloys as well as to steels.

However, in the case of 18–8 austenitic stainless steels rapid cooling results in an annealing process which leaves the metal in the weld zone in its most ductile condition. On this account these steels are better adapted to spot-welded fabrication than any other metal.

(*e*) *Thickness of Sheets.*—With very thin sheets, the welding heat must be delivered in a very short period of time, otherwise it will be conducted off through the electrodes so rapidly that there will be no weld. However, it is often customary in this case to employ a much longer period of current flow than is actually necessary to make the weld. The only objection to this excess time is the extra power consummation which in most cases is not a vital factor.

With thicker material the question as to higher current and shorter time versus lower current and longer time is not so important except in the case of the high conductivity materials discussed above. In fact, in the case of carbon steels, the longer heating time with the consequent greater spread of heat reduces the rate of cooling possibly below the critical rate and may improve the microstructure as well as reduce the residual stresses.

In the case of heavy stainless steel the heating period is restricted to a comparatively low value since the high rate of heating and cooling is essential to avoid carbide precipitation unless stabilized with columbium or titanium.

## ELECTRODES

(*a*) *Material for Electrodes.*—In order to avoid the development of fusion temperature under the electrode tip, two things are necessary: First, the contact resistance must be as low as possible and, second, the conductivity must be as high as possible. Unfortunately, these requirements demand a relatively soft material which is inconsistent with the hardness desired from the standpoint of durability, particularly as to shape. It is customary to strike the best possible compromise between these conflicting requirements. The result is usually a copper alloy with a conductivity from 50 to 80% of that of copper.

There are a few very expensive alloys which combine relative hardness with a somewhat lower conductivity and higher contact resistance. In fact, this higher contact resistance and lower conductivity are both assets in certain cases—for example, in the spot welding of very thin stainless steel where these properties help prevent the otherwise too rapid heat conduction from the weld zone to the electrodes.

If, however, the duration of current flow could be made so short as to make the corresponding heat loss from the weld zone negligible, the above-mentioned assets might become liabilities since, if carried far enough, they might result in fusing the tips to the sheet during the short period of very high current.

This is one of the numerous cases in connection with resistance welding where a quantitative knowledge of the thermal and electrical aspects of the problem is vital to its rapid and rational solution, without the tedious floundering of the blind cut and try process.

(*b*) *Shape of Electrodes.*—For most purposes the part of the tip in contact with the work should preferably be dome shaped with a radius depending upon the thickness and nature of the material, although flat tips are still in considerable use. The shank of the electrode should spread rapidly back of the tip area so as to provide large heat capacity and heat conductance.

(*c*) *Water Cooling.*—Even with the high conductivity of most welding tips it is necessary for heavy-duty service to have them water cooled with the water chamber as close to the end of the tip as possible. Even with the best internal water cooling modern high-production requirements, particularly on heavy work, are occasionally such as to cause undesirable heating of the welding tips and, therefore, more rapid deterioration and deformation. This, in turn, demands more frequent servicing if dependable welds are to be obtained.

In such cases of very heavy duty it is sometimes helpful to employ the interrupted type of current application or what used to be called "woodpecker welding," the chief advantage of which is that the electrode tip has time to cool off slightly between the current impulses. However, the analysis of the thermal phenomena involved, both in the weld zone and under the tip, is very complicated and these phenomena are not thoroughly understood by most of those concerned. In fact, many of the claims made for this type of welding are fallacious and the result of superficial reasoning.

(*d*) *Electrode Pressure.*—Although there are wide differences in practice, it will usually be found that the higher the pressure the more dependable the weld. This is a large and important subject and cannot be treated fully in this brief review.

One factor overlooked in the early days is the weight of the moving part which should follow up very rapidly during the softening period in the weld zone, particularly with short time welds. This is another reason for high electrode pressure, as well as for a light moving part.

In this attempt to explain the "reason why" of some of the limitations of spot welding, it is hoped that we have been able to bring out the vital importance of the accurate control of the major variables, particularly in certain critical cases demanding uniformly good welds, which incidentally, are not the rule. It is a fact that many of those responsible for important spot-welding work do not appreciate the necessity for this accurate control; neither do they know the important influence of slight variations in some of the factors involved. Fortunately, methods of more accurate control have developed rapidly during the past few years. Fortunately, also, for the pioneers in this field, the standards of quality were not high and it was an easy matter to put in extra welds to make up for the inevitably deficient ones. However, at the present time spot welding is being applied to a large number of critical structures where uniformly high quality is absolutely necessary. For such cases, emphasis on accurate control can hardly be too great.

# HIGH-SPEED MECHANIZED Oxyacetylene Welding*

By H. T. HERBST†

FOR purposes of discussion, mechanized oxyacetylene welding can be divided into two broad methods. One might be called the "continuous" method, since by this method the part is completely welded in one continuous operation, such as is practiced in tube welding. The other might be called the "discontinuous" method, where the part is welded with a series of welds, or with two or more welds simultaneously made. This latter method is utilized in making washing-machine tub joints and container seams.

In continuous type of operation the material is carried through the welding machine by a system of rolls and past a stationary welding blowpipe. In the discontinuous method, the preformed stock is placed in a jig and rotated past a stationary welding head or the jig and material may remain stationary while the welding head travels along the seam on a track. As to the technical differences in the welding procedures of the two methods, in the continuous method the material is guided by rolls and the spacing of the edges to be welded can be changed by varying the pressure that the rolls exert. By this means, a gap can be maintained between the edges during preheat, and closed by proper location and pressure of the rolls during the welding. In contrast to this procedure the discontinuous method, which is applied to irregularly shaped pieces, requires that the edges be placed in abutment within the welding jig. In this method all of the heating is done from the top surface of the material and the bottom surface must be heated by conduction, whereas in the continuous method separation of the edges allows direct heating of the entire surface of the edges themselves. This difference in the method of heating the edges for welding, together with the greater heat absorption from stationary clamping jigs used in the discontinuous method, results in a 40 per cent lower gas consumption with the continuous method.

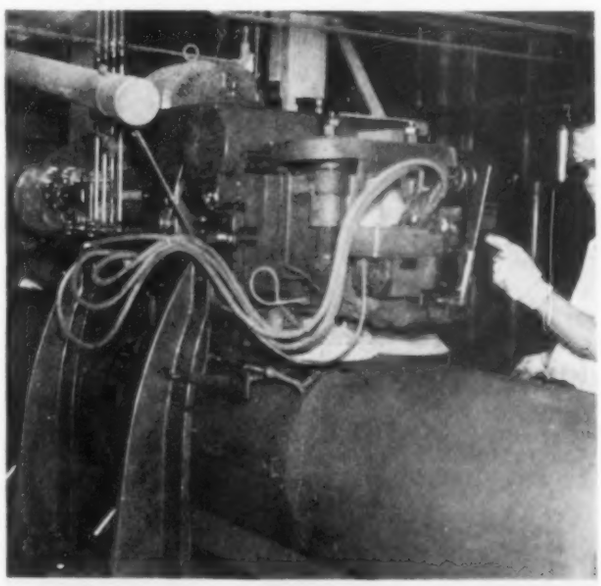
In general the continuous method is limited to straight welds on material of uniform section. The greatest fields of applications for this method, therefore, are longitudinal seam welding of barrels, and tube welding.

In barrel welding variations in stock thickness make necessary automatic control of heat input to the steel. This is accomplished by means of a photoelectric-cell unit which picks up light radiation from the bottom of the weld. This variation also limits the maximum practical welding rates to less than 6 ft. per min. In tube welding of coiled strip stock, these variations do not occur and welding rates in general are limited only by the capacity of the acetylene generator.

The usual practice is to have dual generators installed for continuous service. With a generator installation capable of delivering 600 cu. ft. per hr., tube welding rates of from 75 ft. per min. on 16-gage to over 150 ft. per min. on 20-gage are obtainable. At these rates the coiled stock is fed into a roll-type forming machine with roll forms of a design to give the shape desired. Numerous shapes, such as rectangular, oval or teardrop, can be welded by this method.

From the forming unit, the material passes to the

Fig. 1—Barrels with a 3-Ft. Longitudinal Weld Can Be Turned Out at the Rate of 75 to 100 per Hr. in This Barrel-Welding Machine



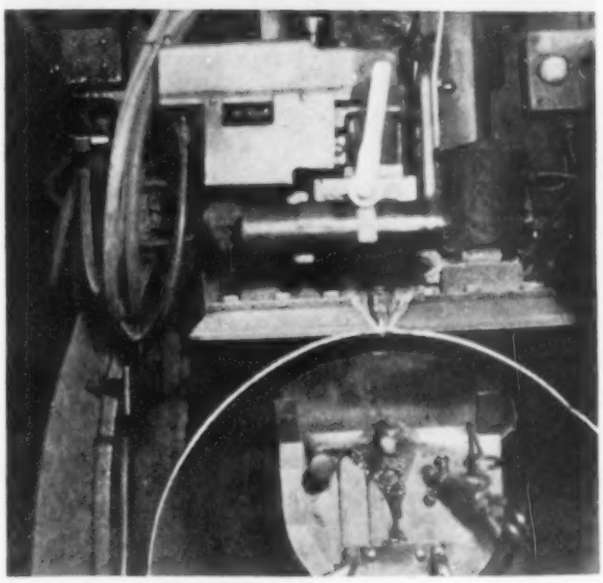


Fig. 2—This End View of the Barrel-Welding Machine Shows the Automatic Control as Well as the Relation Between the Squeeze Rolls, Welding Head and Work

* Paper presented before the Annual Meeting of the AMERICAN WELDING SOCIETY, Cleveland, Ohio, October 20 to 25, 1940.

† Development Engineer, The Linde Air Products Company, Newark, N. J.

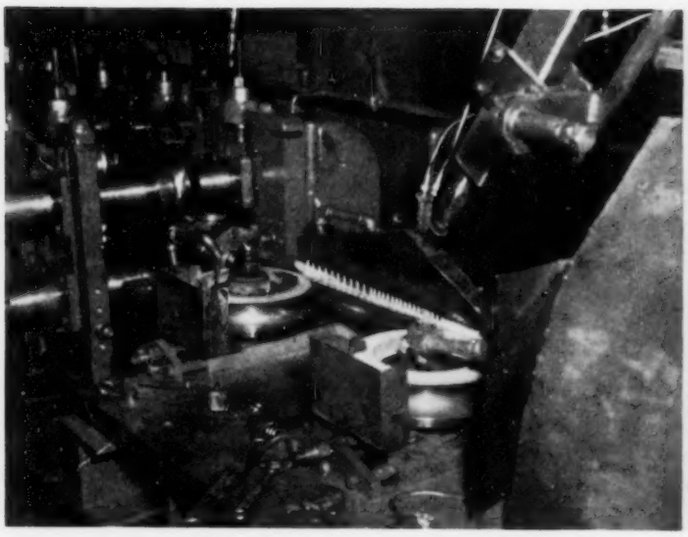


Fig. 3—Welding Speeds as High as 100 Ft. per Min. Are Obtained on Continuous Tube-Welding Machines of This Type

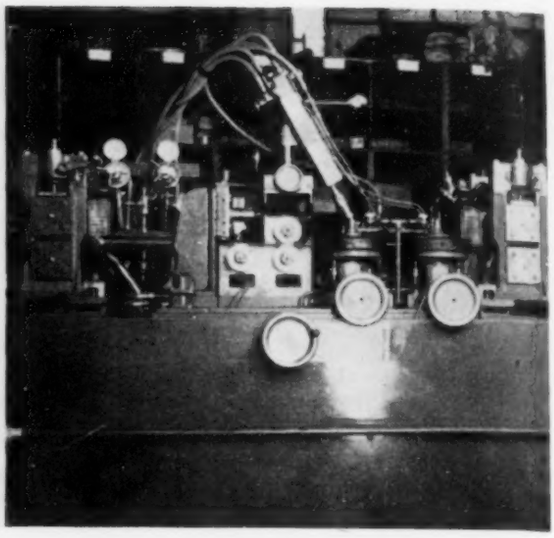


Fig. 4—This Side View of a Tube-Welding Machine Shows the Welding Station and Weld-Trimming Tool. The Welded Tubing Is Used for Conduits in Electrical Fixtures

welding unit which usually is close-coupled to the forming mill. The welding stand generally consists of at least two sets of horizontally and vertically adjustable, water-cooled, side guide rolls. Preheating and welding take place between these two roll sets. With proper side-pressure control of these rolls, the weld reinforcement can be built up or reduced as desired on either the outside or the inside, depending upon the use for which the tube is intended. Where perfectly flush inside and outside surfaces are desired, scarfing tools are employed to trim the weld.

After passing through the welding and scarfing stands, the tube is cooled in a water spray or bath and sized and straightened in rolls provided for this purpose. Then it is cut off to length in an automatic unit that travels with the tube as the cut is being made and returns to its starting position for the next cut.

## DISCONTINUOUS WELDING, NON-ROD FEED

In the discontinuous method of welding with no welding rod, the square-sheared edges of the material are placed in abutment. Since no rod is added it is important that the edges be sheared correctly and placed so that the two edges to be joined are in contact. Failure of the edges to make contact will result in a weld section thinner than the base metal. In some cases, this condition results in burning or falling through of the metal. To avoid deformation due to contraction stress, jigs and clamps used to hold the parts in position should be sufficiently heavy to absorb heat from the workpiece quite rapidly. At high production rates or on small items, it is advisable to provide water-cooling in the jigs for this purpose.

The two most common types of welds made by this

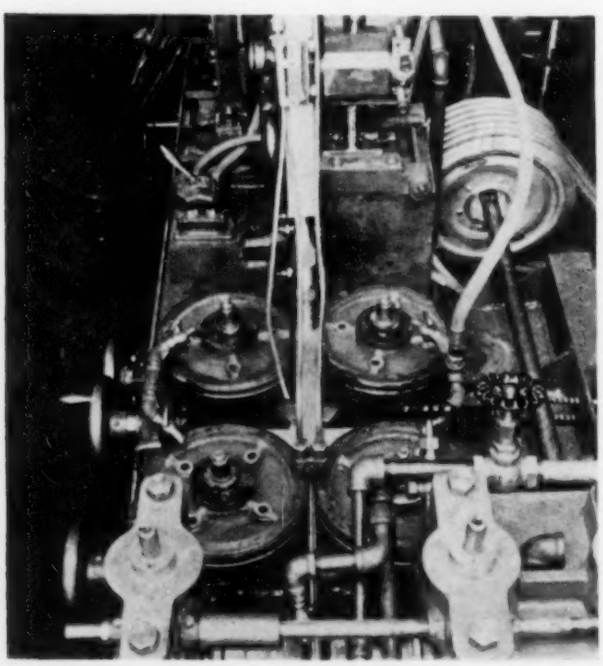


Fig. 5—This Top View of a Tube-Welding Machine Shows the Four Horizontal Rolls Which Position the Tube During Welding

Fig. 6—The Side Seam of This Washing-Machine Tub Is Being Automatically Welded. The Joint, After Cleaning, Is an Ideal Surface for Enameling

Fig. 7—The Stamped Bottom Is Welded to the Previously Welded Side of This Washing-Machine Tub

method are the vertical and girth seam welds on round or rectangular vessels. When the vertical seams are made, the rolled or formed sheet is placed in a clamp with the edges butted together. The weld can be made from either the inside or the outside, depending upon requirements of finish of the completed article. In making this weld, it is preferable to move the welding head with respect to the work. The ends of the container are welded in place next. On round shapes, this girth weld is performed best by revolving the jigs and material beneath the welding head thereby making a flat weld. On rectangular or irregular shapes, the welding head moves around the shape at a uniform rate. This type of operation provides a flush weld with a minimum of reinforcement.

A typical example of this type of weld is found in the manufacture of washing-machine tubs. The tubs consist of two parts, the side wall and the bottom. The side is formed by accurately shearing, rolling and welding a flat metal sheet into a cylinder. In one operation the bottom is stamped from sheet stock and such openings as are required are punched. As the deformation is very slight, wrinkling or stretching of the sheet is avoided. This is of extreme importance in the later enameling operation and has an advantage over deep-drawing methods necessary for one-piece construction. It is the tendency of the deep-drawing operation to produce wrinkled surfaces or thin sections which cause rejections after enameling.

The seamed side and stamped and trimmed bottom are joined by a circumferential weld. The welds are then given a vibrating hammer operation to relieve any strain present and to remove oxide scale. A light grind follows. The tubs are then ready for corrugation and edge-rolling.

A slight variation of this method is applicable to shapes with curved sides that cannot be made by rolling or bending flat sheets. These parts may be stamped or drawn in two halves. These then are placed together in a jig and positioned so that seams are in the same horizontal plane. The joints are then welded simultaneously with two welding heads moved by a common carriage. It should be borne in mind that this method of necessity will proceed at a slower rate than the previously described method, as the horizontal-vertical position of the weld requires a smaller weld puddle.

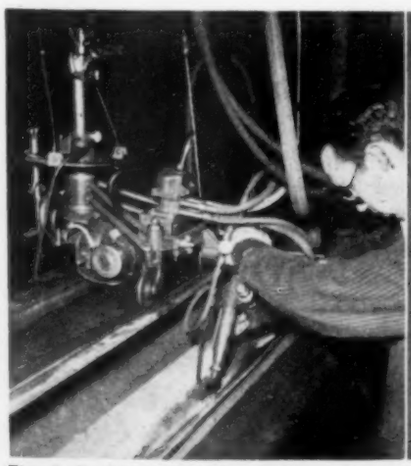


Fig. 8—Leakproof Welds Are Economically Made in Gasoline Tanks by Mechanical Welding

Fig. 9—This View Shows the Completed Tank. Note the Neat Appearance of the Mechanically Welded Joints

## STRIP WELDING

There are numerous applications of strip welding to which automatic oxyacetylene welding is well suited. The softness of the weld lends itself to double- or triple-lengthening of hot-rolled coils before the initial pass in the cold-reduction mill. In this case, a weld zone that is not appreciably harder than the base metal is required to avoid marring the surface of the cold-working rolls. In addition to this, the weld strength and reliability must be such as to preclude breakage while going through the cold mill. By means of special rolls and clamping arrangements, welds are made on 10-gage material with full penetration and strength without the use of welding rod. Two further advantages of this weld are the elimination of necessity for flash-stripping or grinding after the weld is made, and the speed of operation suitable for a recoiling or processing line.

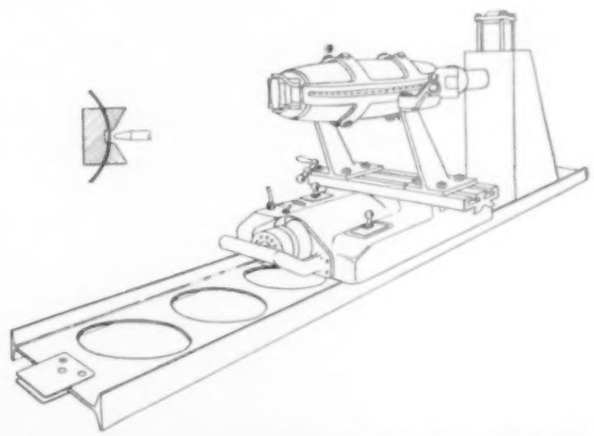


Fig. 10—In Simultaneously Making Two Welds on the Curved Surface of Stamped Shells, Two Blowpipes Are Carried by a Cutting-Machine Carriage and Are Positioned by Guide Rolls

Another application is for the welding of coils together in steel mills to meet customer demands for coils of greater length. Here the further advantages of low-cost installation and great flexibility in handling wide ranges of gages and widths are obtained.

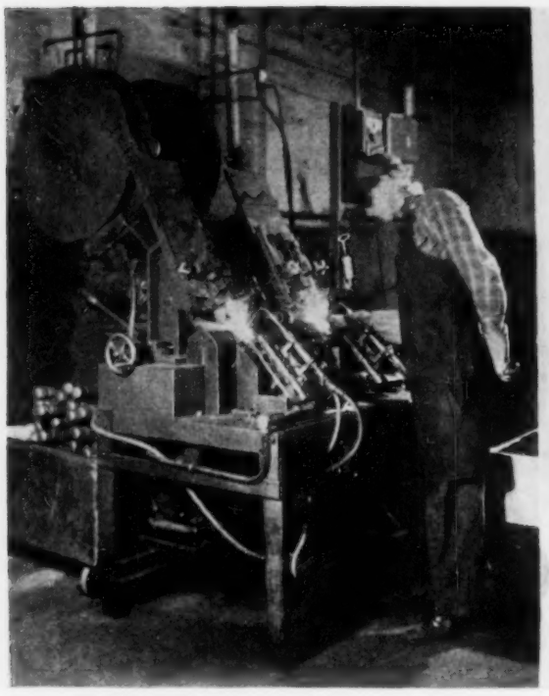
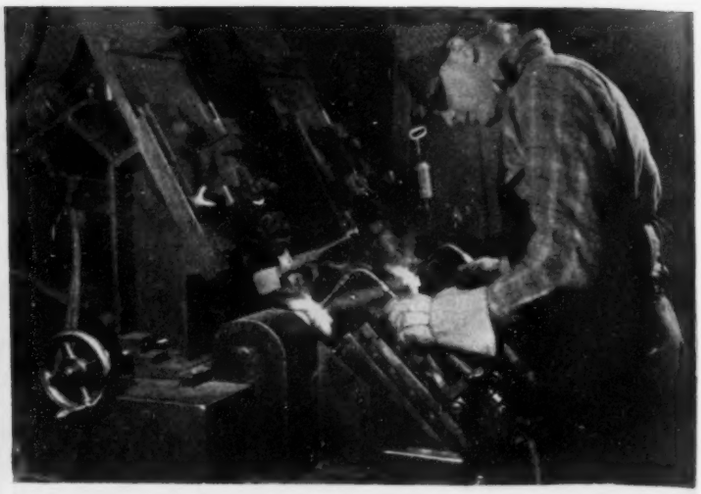


Fig. 11—Two Caps Are Being Simultaneously Welded to the Ends of 2½-Inch Diam. Tubing. The Parts Are for an Automatic Refrigerator



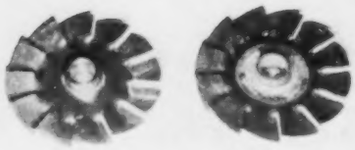


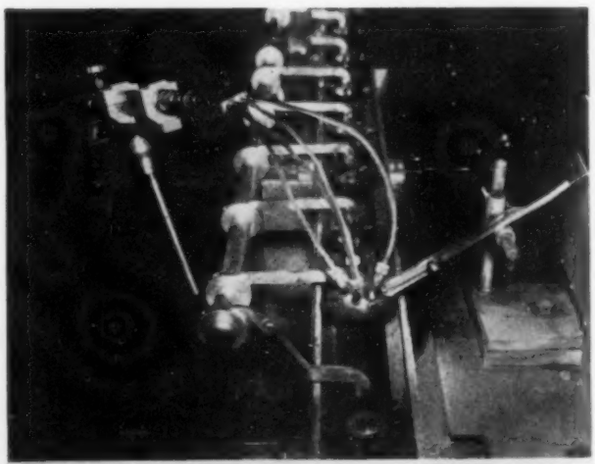
Fig. 12—This Close-up Shows the Position of the Blowpipes and Automatic Rod-Feed Mechanism with Respect to the Refrigerator Parts. Welds Are Later Subjected to a Test Pressure of 1000 Lb. per Sq. Inch

Fig. 13—Hubs Are Automatically Bronze-Welded to Stamped Fan Blades at the Rate of 3000 to 4000 per Day. Left, Hub in Place Ready for Welding; Right, Completed Fan

## HEAVY WELDING WITH WELDING ROD

To obtain full-strength welds on material of 12-gage and heavier, other than flat sheets, welding rod is used. The rod feed is made automatic through a variable-speed feed mechanism. A single welding head that has several flames so designed as to fulfil the various operations of rod preheat, plate preheat and welding generally is used. This method is suited particularly to the fabrication of cylinders and tanks requiring joints that are leakproof to dry gases.

One example of this method is in the fabrication of the pressure chamber of a household gas refrigerator. This pressure chamber consists of a length of 2½-inch tubing with caps welded on either end. These two welds are made simultaneously on an automatic machine equipped with two welding blowpipes and a motor-driven rod feed using coiled welding rod. Here the requisite leakproof



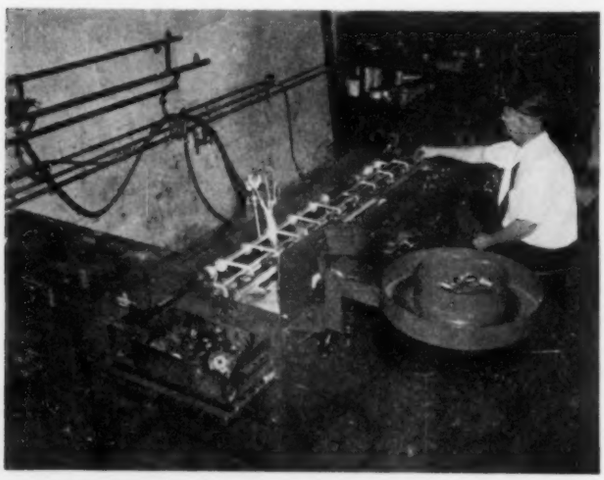


Fig. 14—This Is a General View of the Machine Used for Bronze-Welding Fans. In the Foreground Are Shown the Wire Reel and Tote Box Containing Completed Fans

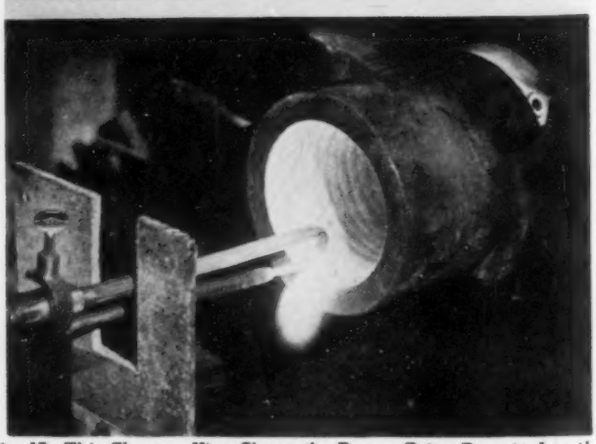


Fig. 15—This Close-up View Shows the Bronze Being Deposited to the Revolving Fan Blade

Fig. 16—Depositing a Bronze-Bearing Surface as a Cylinder Lining Is Automatically Performed

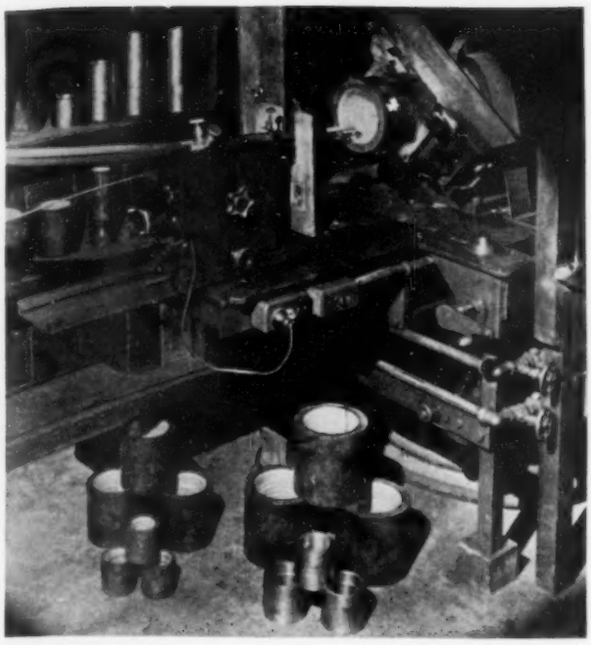


Fig. 17—This Is the Set-up for Depositing the Bronze-Bearing Surface. On the Floor Are Several Completed Cylinders

joints are obtained at high production rates and with a minimum number of rejects.

This process is also applied on similar but larger machines for the production of cylinders used in shipping gases for industrial and home-cooking purposes. Here two half-shells are drawn and joined with an automatic oxyacetylene girth weld. This construction results in lower costs than the method previously used wherein the tank was made from one full-length drawing with a dished head locked and dip-brazed in place.

## AUTOMATIC BRONZE-WELDING

The process described above for fusion welding also can be applied to bronze-welding. The necessary fluxing action required is provided most conveniently by the use of a volatile liquid flux.

A variation of this process also is suitable for the assembly of steel parts on a production basis, such as the assembly of a fan for a portable electric-drill motor. Here a sheet stamping is bronze-welded to a machined hub. Except for loading, operation of the machine is fully automatic. The hub and fan, staked together, are loaded at one end in any of the first four of ten positions. Then ten equally spaced positioner fingers intermittently move all units on the track to the next position. The next four positions are for preheat burners located beneath the fans so that each unit, as it is moved along, is preheated at four positions. When each fan unit reaches the ninth position, a rotating stem automatically rises and engages the fan hub. At the same time, the blowpipe tips lower into position for the welding operation, and the welding rod is fed automatically at a predetermined rate from a reel. The stem under the ninth or welding position both raises the unit into position and revolves it during the bronze-welding operation. At the tenth position, the tenth finger moves the completed fan into a tote box. The various parts of the machine are adjustable to accommodate a variety of sizes. The average actual welding time is 3 sec. and the average production rate is 10 to 12 units per min.

A different type of operation is represented in the mechanized application of bronze for bearing surfaces. A typical example is the bronze-surfacing of the cylinder lining for a rotary pump operating at 2000 lb. per sq. inch. Here a layer of bronze is deposited on the steel surface which will later be machined, leaving a non-porous surface. Bronze-rod feed and blowpipe movement are provided by a motor-driven carriage. While the part being treated is slowly revolved, the blowpipe is moved across the surface. Volatile liquid flux, introduced to the flame with the acetylene, leaves no deposit of slag to be removed. The rate of deposition of the metal is 55 inches per min. This installation replaces hand operation at a saving of about 50 per cent in both bronze and gas.

Today the rapid method of mechanized oxyacetylene welding is being adopted to reduce costs, improve product quality and increase production. Installation costs are extremely low in comparison with competitive automatic welding equipment. Lower cleaning and maintenance costs and decreased reject losses usually make over-all operating costs comparable to other automatic welding methods which are notably less adaptable to changing production methods. It is universally recognized that oxyacetylene mechanized welding has a high degree of flexibility. Where a smooth, clean surface is required, gas welding often can be used when other mechanized methods would necessitate subsequent cleaning or grinding of the piece. With the properly designed heads available today, production rates with mechanized oxyacetylene welding are greater in many cases than those obtained with other automatic equipment. This is due in part to the greater welding speeds and in part to shorter set-up time of the mechanized oxyacetylene equipment.

# INVESTIGATION OF GAS AND Arc Fillet Welds in Piping*

By IRVING H. CARLSON† and
ERIC R. SEABLOOM‡

ASSEMBLY of piping systems by means of oxy-acetylene and electric arc welding has been employed quite extensively for many years. More recently, tremendous strides have been made in applying fusion welding to pipe fabrication, especially with the advent of higher pressures and temperatures. Under the severe operating conditions imposed upon piping today, welding has become almost a necessity in overcoming the difficulties experienced with most mechanical joints subject to elevated temperatures. To aid piping erectors in extending the use of welding, manufacturers have placed on the market numerous fittings, such as elbows, tees, crosses, reducers, caps, flanges and valves with ends prepared for welding. The majority of these fittings are provided with scarfings to form single V or U circumferential butt welds, as this type of joint is the most popular due to the fact that Codes allow its use for all pressures and temperatures.

Fillet welds have been employed to a limited extent even though they offer certain advantages over butt welds, particularly on small sizes of piping. The reason for this lack of popularity in the use of fillet welds has been the restrictions placed on them by the A. S. A. Code for Pressure Piping, as well as other Codes governing pipe welding. According to the present published Code for Pressure Piping, fittings and flanges fillet welded to pipe can only be used at a maximum pressure of 300 lb. per sq. in., which is a very conservative rating.

During the last three years the above-mentioned Code has been in the process of complete revision, including the sections pertaining to welding. The Fabrication Details Committee of this Code, as well as a sub-group of Subcommittee 3 of A. S. A. B-16, gave very careful consideration to proposals by industry to increase pressure and temperature ratings on fillet welds. Some manufacturers and users of fillet or socket welding fittings submitted test data and field experience on fillet welds, which definitely indicated that the ratings could be made equivalent to those on butt welds. These committees agreed at first to give unlimited ratings to fillet welds as applied to pipe fittings 2 inches and smaller, then, at a later discussion, included 3 inches and smaller, and finally drafted rules permitting their use on all sizes. The proposed revisions have not yet been published but will appear in the Code when it is reprinted in the early part of next year.

To further indicate that fillet welds are finding greater acceptance, it might be mentioned that the A. S. M. E. Boiler Construction Code, which also maintained the same restrictions on fillet welds, namely, 300 lb. working pressure, recently published a revision as an interpretation of Paragraph P-112 (Case No. 888), permitting socket type fillet-welded joints to be used on piping 4 inches and smaller without limitations as to pressures and temperatures.

The regulations pertaining to slip-on fillet-welded flanges have not been altered, the basic 300 lb. 750° F. rating still being retained by both the Code for Pressure Piping and the A. S. A. B-16e Steel Flange Standards. However, the latter tabulates adjusted pressure-temperature ratings and permits 300-lb. flanges to be used at a maximum pressure of 500 lb. at 100° F. temperature. The reason for this conservatism as applied to flanges is that some Code authorities are firm in their beliefs that additional high stresses are imposed upon the fillet welds through the relatively short hubs incorporated on A. S. A. flanges, when bolt loads are applied. This does not appear to be wholly justified.

Apparently, the lack of enthusiasm by engineers for fillet weld has been due to the fact that they are subject to high stress concentrations, as revealed by photoelastic investigations conducted with celluloid or bakelite models in polarized light. Reproductions from photoelastic studies, as shown by Fig. 1, illustrate comparative stress lines obtained on fillet and butt welds. It will be observed that the stress concentration at the root of the fillet weld and at the junction between the weld and the pipe is of a high magnitude, due to the notch effects The stress values are several times greater than the normal stress in the section and also much higher than in a perfect butt weld, but approach those obtained in butt welds having such defects as incomplete fusion at the root or undercutting along the reinforcement. Generally, such localized stresses will not greatly affect the strength of the welded assembly, except to lower the fatigue value. However, the endurance limit of fillet-welded joints is remarkably high when compared to screwed joints, which have been used and accepted for many years.

The outstanding advantage of socket type fillet welds over butt welds, particularly on small sizes of piping, is that complete fusion between the sockets and pipe is readily obtainable without much danger of burning through the pipe walls and forming icicles or slag. Furthermore, backing rings are not necessary, thus eliminating all restrictions to fluid flow. Backing rings are used to a great extent on butt welds, especially in field welding of piping, as an assurance of obtaining thorough fusion. On small sizes they absorb an appreciable part of the internal pipe area, and as a consequence are mostly employed on larger diameters. Other advantages of socket type fillet welds are (1) the pipe does not require beveling, and (2) the pipe ends slip into and are supported by the sockets; hence, the joints are virtually self-aligning, thus avoiding the necessity of tack welding or clamping prior to welding. Also, upon erection of piping, where streamline flow is not absolutely essential, the depth of the socket bore provides some come and go, so that it is unnecessary to cut the pipe to accurate length or even to cut it off square. This feature saves appreciable time, speeds up installation and thereby reduces erection costs.

For some years past, manufacturers have furnished the

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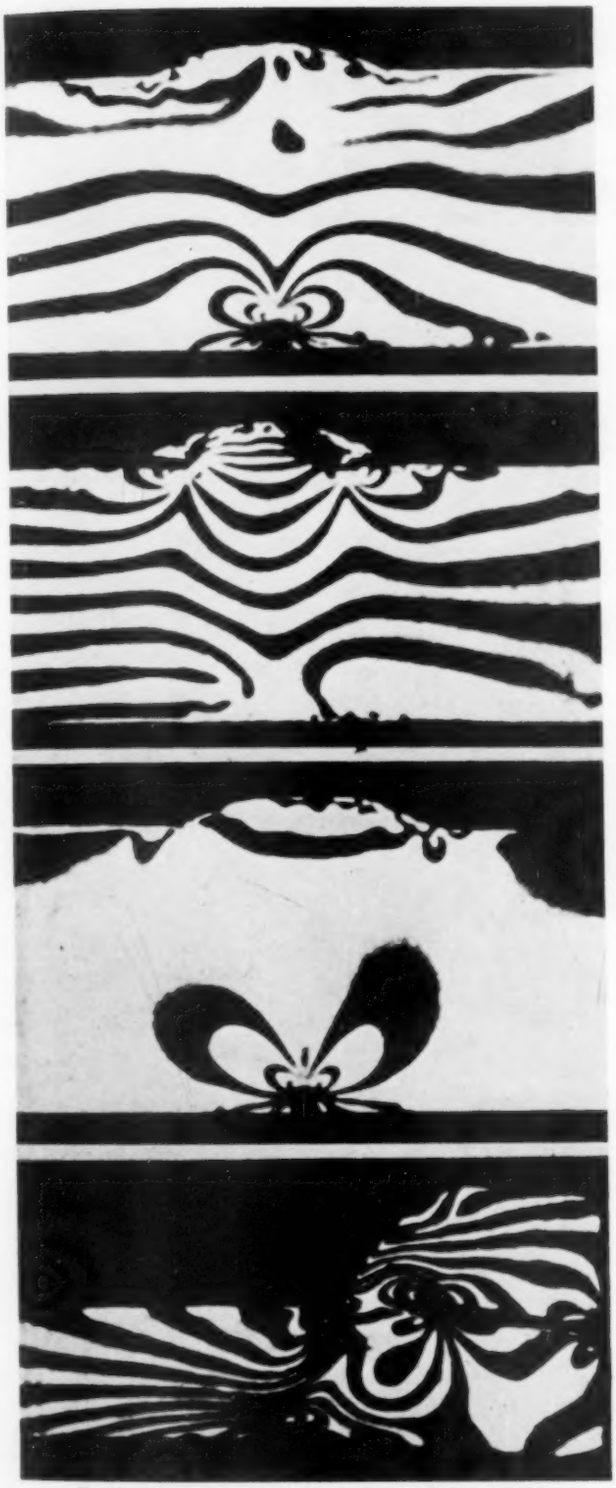


Fig. 1—Stress Concentrations in Butt and Fillet Welds

trade forged-steel, socket type fillet-welded fittings, but these have generally been made from screwed fitting forging blanks, their ends being bored out with a socket rather than tapped for pipe threads. The thickness of the bands or socket walls of the fittings in respect to the pipe wall thickness was quite heavy because they were primarily designed for screwed joints. This has caused some trouble for welding operators in producing quality welds, due to the fact that either the thinner pipe wall sections had a tendency to overheat, or lack of fusion would occur between the weld metal and the heavier socket wall section due to underheating. Furthermore, welders often built up the fillets to meet the outside diameters of the sockets, and the resultant welds were much heavier than necessary, adding to the time, material and cost. As a result, some manufacturers have endeavored to overcome these difficulties by redesigning fittings for fillet welding by providing bands or socket walls that approach the thickness of the pipe, insuring more uniform heat distribution between the parts to be joined. Figure 2 shows fillet welds on socket type fittings, one made from a screwed fitting forging blank and the other a fitting designed for welding.

Our investigation of fillet welds was primarily made in connection with the designing of a new line of forged steel socket type fillet welding fittings and incorporated studies of weld strength in relation to sockets and pipe. The tests which were conducted on assemblies of $^1/_4$-inch to 2-inch tees, couplings and pipe joined by the oxyacetylene and electric arc methods of fusion welding, included standard and extra heavy seamless A. S. T. M.–A 106 pipe in both low and medium carbon grades. These consisted of hydrostatic bursting pressure tests, tensile tests, fatigue studies, metallographic examination and hardness surveys.

## WELDING PROCEDURE

All welds were made with the short lengths of pipe in a vertical position without clearance between the pipe ends and the socket shoulders of the fittings. The welds were made by Code qualified operators chosen at random from the fabricating shop, no attempt being made to select exceptionally skilled men. The weld contours were approximately in the form of 30–60° triangles, as shown by representative macrographs illustrated by Fig. 3. It appeared to be a natural tendency for the welders to produce welds of this shape when joining approximately equal thicknesses. This is certainly to be preferred to welds having 45° angle or convex cross sections, because of reduced stress concentration.

The oxyacetylene welds were made with a single pass, using $^1/_{16}$-inch diameter rod on $^1/_4$-inch to $^3/_4$-inch fittings and $^1/_8$ inch diameter on the larger sizes. All of the arc welds were made by depositing two layers of weld metal employing $^1/_8$-inch diameter coated electrodes. It was noted that smoother fillet welds could be obtained with the oxyacetylene torch than with the arc, particularly on sizes below 1-inch pipe. Smoothness of weld contour

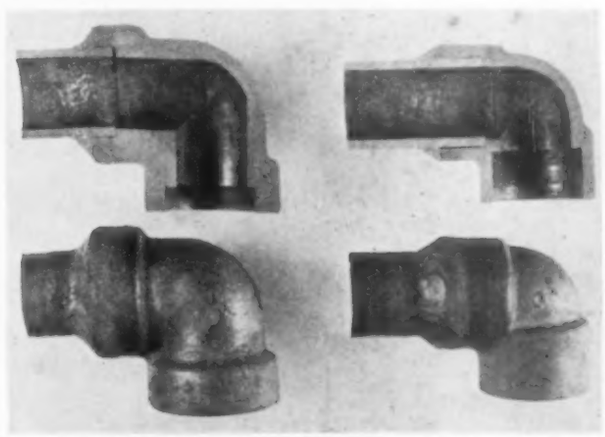


Fig. 2—Fillet Welds Made to Conventional Screwed Fitting Forging and Fitting Designed for Welding

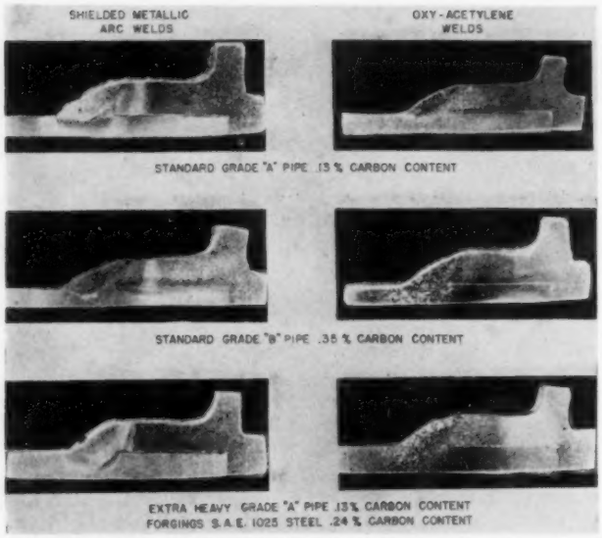

SHIELDED METALLIC ARC WELDS
OXY-ACETYLENE WELDS
STANDARD GRADE "A" PIPE .13 % CARBON CONTENT
STANDARD GRADE "B" PIPE .35 % CARBON CONTENT
EXTRA HEAVY GRADE "A" PIPE .13% CARBON CONTENT
FORGINGS S.A.E. 1025 STEEL .24 % CARBON CONTENT

**Fig. 3—Representative Fillet Welds Used in Tests. Note Approximate 30–60° Weld Contours**

has an important bearing on the fatigue life, as will be discussed later.

## HYDROSTATIC PRESSURE TESTS

Destructive tests were made on four tees of each size, $^1/_4$ inch to 2 inches, inclusive, welded to standard Grade *A* pipe and four of each size to extra strong Grade *A* pipe. In addition, four tees of each in the $^3/_4$-inch, $1^1/_4$-inch and 2-inch sizes were welded to standard Grade *B* and extra strong Grade *B*, making a total of 88 assemblies, half of which were gas welded and half arc welded. The lengths of pipe joined to the tees were rather short, ranging from 6 inches on the smaller sizes to 10 inches on the larger sizes. Short lengths were employed in preference to long lengths, because the strengthening effect afforded by the end closures permitted higher bursting pressures, thus imposing greater stresses on the fillet welds and fittings.

Hydrostatic pressure was built up gradually on the assemblies, until failures occurred, by means of a hydraulic displacement machine, capable of developing pressures in excess of 50,000 lb. per sq. in. During the pressure tests diametral deformation readings were taken on the fittings by means of dial indicators up to the yield point of the material, but, as the results have no connection with this paper, the data have not been included. The average bursting pressures are recorded in Table 1, each figure representing an average of four for each size, two gas welded and two arc welded. Typical failures are shown in Fig. 4. For comparison, theoretical bursting pressures of pipe, calculated from Barlow's formula, are included in the table, i.e.,

$$\left(\text{Bursting Pressure in psi} = \frac{2T \times T.S.}{O.D.}\right)$$

where $T$ = pipe wall thickness
$T.S.$ = tensile strength in lb. per sq. in.
$O.D.$ = outside diameter of pipe

using the minimum tensile strength specified for A. S. T. M.—A 106 seamless pipe of 48,000 lb. per sq. in. for Grade *A* and 62,000 lb. per sq. in. for Grade *B*.

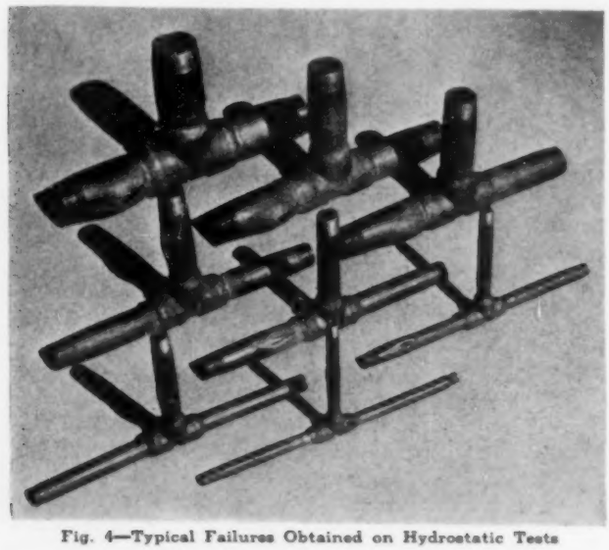


**Fig. 4—Typical Failures Obtained on Hydrostatic Tests**

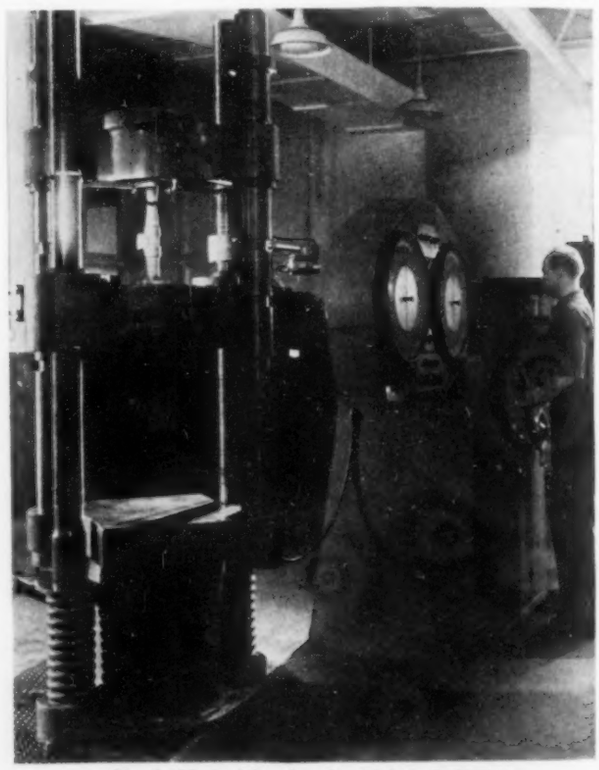


**Fig. 5—Method Employed in Making Pull Tests**

Of the 88 assemblies, comprising 264 fillet-welded joints, only one fracture occurred in a weld, and this happened on a $1^1/_4$-inch tee with extra strong weight Grade *B* pipe, gas welded. However, the internal pressure to cause rupture was 16,000 lb. per sq. in., which exceeded the failure pressures of 14,700, 15,000 and 15,250 lb. on similar combinations. In every case the pressures to cause failures were considerably in excess of the minimum theoretical bursting pressures of average lengths of pipe.

## TENSILE TESTS

Pull tests were made on another set of 88 welded tee assemblies, identical in every respect to those used on the hydrostatic tests, with the exception that fillet-welded joints were only incorporated in the run openings

**Table 1—Hydrostatic Bursting Pressures (Pounds Per Square Inch)**

| Size of Fitting and Pipe, Inches | Grade A Seamless Steel Pipe: Welded Assembly by Actual Test | Grade A Seamless Steel Pipe: Theoretical Bursting Pressure of Pipe Alone | Grade B Seamless Steel Pipe: Welded Assembly by Actual Test | Grade B Seamless Steel Pipe: Theoretical Bursting Pressure of Pipe Alone |
|---|---|---|---|---|
| **Standard Weight Pipe and Tees** | | | | |
| 1/4 | 22,360 | 15,644 | Not Tested | |
| 3/8 | 17,680 | 12,942 | Not Tested | |
| 1/2 | 18,180 | 12,457 | Not Tested | |
| 3/4 | 13,440 | 10,331 | 16,250 | 13,344 |
| 1 | 13,750 | 9,709 | Not Tested | |
| 1 1/4 | 11,310 | 8,096 | 12,190 | 10,457 |
| 1 1/2 | 9,190 | 7,326 | Not Tested | |
| 2 | 8,880 | 6,224 | 10,310 | 8,040 |
| **Extra Strong Weight Pipe and Tees** | | | | |
| 1/4 | 27,620 | 21,155 | Not Tested | |
| 3/8 | 25,000 | 17,920 | Not Tested | |
| 1/2 | 21,950 | 16,800 | Not Tested | |
| 3/4 | 20,000 | 14,080 | 19,900 | 18,186 |
| 1 | 16,810 | 13,067 | Not Tested | |
| 1 1/4 | 14,500 | 11,045 | 15,250 | 14,267 |
| 1 1/2 | 13,060 | 10,105 | Not Tested | |
| 2 | 12,380 | 8,811 | 14,310 | 11,361 |

using 11-inch lengths of pipe, making a total of 176 welds. These were subjected to combined tensile and shear loads in a 200,000-lb. hydraulic tensile machine until breakage occurred, as shown in Fig. 5. Results are given in Table 2 and each figure is an average of four specimens, two gas welded and two arc welded. Figure 6 illustrates typical failures.

In this test not a single weld showed any signs of failing, the pipes fracturing in all cases at a distance ranging from $^3/_4$ inch to 5 inches away from the welds, and there was no difference in results with welded joints made by either process.

The favorable results obtained with fillet welds on the hydrostatic and tensile tests brought up the question of whether the test welds were representative of those that might be produced under somewhat adverse field conditions. Many of the welds used on these tests were sectioned, polished and etched, and were found to be sound, practically free from injurious defects. The general opinion was that the welding possibly was of somewhat higher quality than could be expected in most field erections, due to advantages in positioning, plus the strict procedures and supervision employed in the shop. Realizing that welding operators, even though Code qualified, probably could not produce equal quality in field fabrications, where most of the welding is performed in fixed positions and sometimes in very inaccessible places, it was decided to conduct additional tensile tests. Realizing that it would be difficult to simulate welds containing certain defects, as might result from unfavorable positioning, we prepared several welded assemblies, wherein the nominal sizes of the fillets were less than pipe wall thickness to represent a weaker variety. These were compared with welds having equivalent thickness of pipe.

In the tests previously described, the socket walls ranged in thickness from that of pipe to somewhat heavier than pipe, as shown in Table 3.

When a socket fitting is welded to pipe the fillet weld is built up from the outer circumference of the pipe to meet the outer circumference of the socket. Consequently, if the socket is the same thickness as the pipe, then the transverse area of the socket is approximately 125% that of the pipe, because of the greater circumference. The tensile strength of a fillet weld, however,

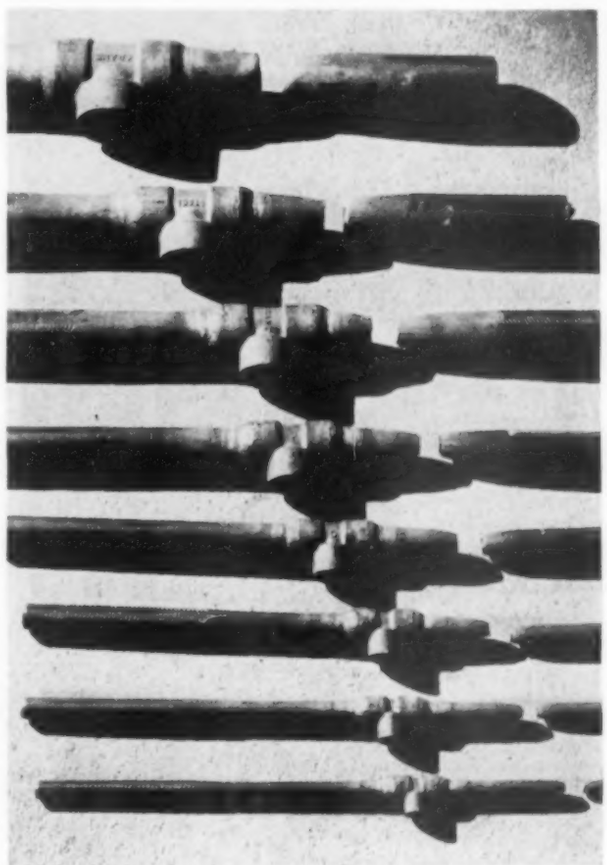


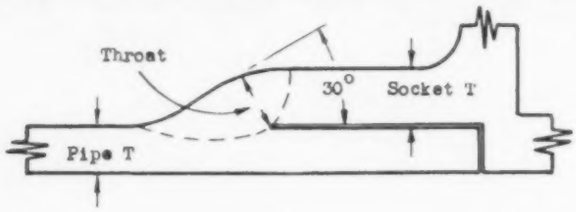
Fig. 6—Typical Failures Resulting from Pull Tests

**Table 2—Tensile Pull Tests (Total Load in Pounds)**

| Size of Fitting and Pipe, Inches | Standard Seamless Steel Pipe Welded to Tees: Using Grade A Pipe | Standard Seamless Steel Pipe Welded to Tees: Using Grade B Pipe | Extra Strong Seamless Steel Pipe Welded to Tees: Using Grade A Pipe | Extra Strong Seamless Steel Pipe Welded to Tees: Using Grade B Pipe |
|---|---|---|---|---|
| 1/4 | 7,025 | Not Tested | 7,860 | Not Tested |
| 3/8 | 9,225 | Not Tested | 11,910 | Not Tested |
| 1/2 | 13,000 | Not Tested | 17,950 | Not Tested |
| 3/4 | 17,375 | 22,540 | 24,910 | 25,500 |
| 1 | 30,840 | Not Tested | 36,940 | Not Tested |
| 1 1/4 | 40,425 | 52,100 | 51,800 | 69,150 |
| 1 1/2 | 46,150 | Not Tested | 58,560 | Not Tested |
| 2 | 66,775 | 79,425 | 90,680 | 111,150 |

is computed on the throat dimension of the triangular cross section of the weld metal. For a fillet weld having a throat dimension of 0.8 the nominal size of the weld and a 30° approach with the pipe, from a socket equal to pipe thickness, thus giving the socket $1^1/_4$ times the cross-sectional area of the pipe, the conical-shaped throat area of the weld will be practically equivalent to pipe wall area. Hence, if the physical properties of the deposited metal are the same as those of the pipe, then a fillet weld should display equal strength to pipe, providing the weld metal is sound and thoroughly fused with the base metals. However, most weld metals have superior strength characteristics over carbon pipe materials.

Table 3—Dimensions and Areas of Pipe, Sockets and Welds Used in the Hydrostatic and Tensile Tests




| SIZE | O.D. OF PIPE | STANDARD PIPE | | | | | | EXTRA STRONG PIPE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | THICKNESS | | TRANSVERSE AREA | | | % AREA THROAT / PIPE | THICKNESS | | TRANSVERSE AREA | | | % AREA THROAT / PIPE |
| | | PIPE | SOCKET | PIPE | SOCKET | THROAT | | PIPE | SOCKET | PIPE | SOCKET | THROAT | |
| 1/4 | .540 | .088 | .129 | .129 | .276 | .224 | 179 | .119 | .129 | .157 | .276 | .224 | 143 |
| 3/8 | .675 | .091 | .139 | .167 | .363 | .296 | 177 | .126 | .139 | .217 | .363 | .296 | 137 |
| 1/2 | .840 | .109 | .148 | .250 | .469 | .382 | 153 | .147 | .148 | .320 | .469 | .382 | 119 |
| 3/4 | 1.050 | .113 | .152 | .333 | .586 | .483 | 145 | .154 | .152 | .433 | .586 | .483 | 112 |
| 1 | 1.315 | .133 | .176 | .494 | .837 | .690 | 140 | .179 | .176 | .639 | .837 | .690 | 108 |
| 1 1/4 | 1.660 | .140 | .191 | .669 | 1.125 | .935 | 140 | .191 | .191 | .881 | 1.125 | .935 | 106 |
| 1 1/2 | 1.900 | .145 | .196 | .799 | 1.305 | 1.093 | 137 | .200 | .196 | 1.068 | 1.305 | 1.093 | 102 |
| 2 | 2.375 | .154 | .219 | 1.075 | 1.812 | 1.516 | 141 | .218 | .219 | 1.477 | 1.812 | 1.516 | 103 |

As mentioned previously, it would be difficult to produce test welds with inherent defects, as might be obtained under adverse welding conditions. In this connection, the following additional work was conducted. Special socket couplings were made from S. A. E. 1025 carbon steel bar stock in the 1-inch and 2-inch sizes. Three of each size were machined with the socket walls reduced in thickness to give the same transverse areas as extra strong pipe, so that the welds would represent poorer quality and strength. These were compared with similar couplings, which were made with sockets having the same thickness as extra strong pipe, giving 125% pipe wall area. All of the couplings were welded to extra strong A. S. T. M.-A 106 Grades *A* and *B* pipe, using the oxyacetylene process with the same procedure as formerly described. The assemblies were pulled in the tensile machine with results as outlined in Table 4 and illustrated in Figs. 7, 8, 9 and 10.

It will be observed from the test data that only three of the six assemblies using Grade *B* pipe, and with sockets having equivalent transverse area to that of the pipe, failed in the welds. The tensile loads to cause failure were in the same range as those that fractured in the pipe. All of the other combinations, including equal socket and pipe areas with Grade *A* pipe, as well as equal thickness of sockets and pipe welded to both Grades *A* and *B* pipe, failed outside of the welds. Calculations from the test data indicate that the tensile strength of the weld metal somewhat exceeded that of even Grade *B* pipe, and this fact is generally accepted. The tests show that defects in the deposited metal, equivalent to reduce the effective transverse weld area to that of the pipe, will possibly result in weld failure if loads approaching the ultimate strength of Grade *B* medium carbon pipe are imposed upon a piping installation. However, with the more commonly used Grade *A* pipe, failure in the welds with equal transverse area probably will never occur in tension, as their physical properties generally exceed those of low carbon pipe by a good margin. If, on the other hand, the weld metal is of approximately the same tensile strength as the pipe material, which is all that is required by the latest proposed draft of the Code for Pressure Piping, then the chances are about equal to have either the pipe or weld fail under high tensile loading when the socket and pipe are of the same thickness.

## HARDNESS EXPLORATIONS

Extensive hardness surveys were made on sections removed from assemblies comprising 1-inch tees, standard and extra strong pipe in both Grades *A* and *B*, fillet welded by oxyacetylene, as well as by electric arc methods. The specimens were ground, polished and lightly etched to reveal the various zones. The hardness readings, as shown in Table 5, were determined on a Vickers hardness testing machine, and are expressed in Vickers pyramidal numbers, which are substantially the same as Brinell numbers within the range covered.

The chemical composition of the tees and pipe used in

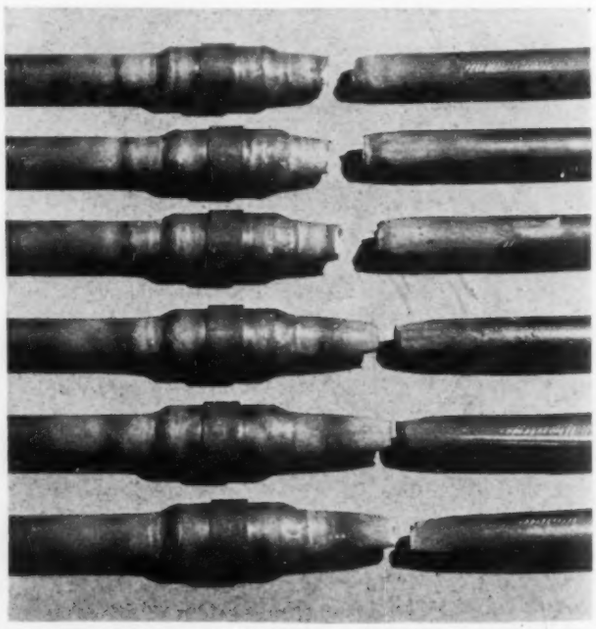


Fig. 7—Tensile Failures of 1-Inch Assemblies Having Sockets and Pipe of Equal Thickness

**Table 4—Tensile Load to Cause Failures of Oxy-Acetylene Welded Assemblies Having Socket Wall and Pipe of Equal Thickness vs. Socket Wall and Pipe of Equal Area**

| Size of Joint | | 1" | | 2" | |
|---|---|---|---|---|---|
| Socket Wall | % of Pipe Thickness | 95.5 | 78 | 105 | 85 |
| | % of Transverse Area of Pipe | 189 | 100 | 123 | 100 |
| O.D. of Socket | | 1.6675" | 1.615" | 2.84375" | 2.775" |
| Bore of Socket | | 1.335" | 1.335" | 2.405" | 2.405" |
| Thickness of Socket | | .1763" | .14" | .2194" | .185" |
| Thickness of Pipe | | .179" | .179" | .218" | .218" |
| Ultimate Tensile Load in Pounds to Cause Failure | | | | | |
| | | Extra Heavy Grade A Pipe | | | |
| Sample No. | 1 | 37,650 | 40,150 | 87,200 | 86,800 |
| | 2 | 38,500 | 38,100 | 89,200 | 86,900 |
| | 3 | 37,400 | 37,800 | 87,500 | 87,400 |
| Average | | 37,850 | 38,683 | 87,966 | 87,000 |
| Nature of Failure: | | No failure in weld. The pipe failed in each case, a distance varying from 1" to 2 7/8" from weld. | | | |
| | | Extra Heavy Grade B Pipe | | | |
| Sample No. | 4 | 51,000 | 47,500* | 109,200 | 111,300 |
| | 5 | 53,000 | 49,700 | 111,500 | 111,100* |
| | 6 | 50,200 | 50,450 | 112,200 | 100,000* |
| Average | | 51,400 | 49,250 | 110,966 | 107,466 |
| Nature of Failure: | | No failure in weld. Pipe failed. | *Sample #4 failed in weld. Failure in pipe only on other samples. | No failure in weld. Pipe failed. | *Sample #5 & #6 failed in weld. Sample #4 failed in pipe only. |
| FIG. NO. | | 7 | 8 | 9 | 10 |

the assemblies from which hardness surveys were made are as follows:

| Description | Chemical Analysis Si | Mn | S | P | C |
|---|---|---|---|---|---|
| Socket Tee | | 0.58 | 0.017 | 0.012 | 0.24 |
| Standard Grade *A* | 0.30 | 0.50 | 0.022 | 0.017 | 0.13 |
| Standard Grade *B* | 0.21 | 0.84 | 0.023 | 0.023 | 0.35 |
| Extra Strong Grade *A* | 0.21 | 0.53 | 0.030 | 0.015 | 0.13 |
| Extra Strong Grade *B* | 0.18 | 0.98 | 0.030 | 0.023 | 0.26 |

The hardness values obtained are within the range generally acceptable for pressure piping, although the results indicate that preference should possibly be given to the lower carbon ranges in Grade *B* pipe.

## METALLOGRAPHIC EXAMINATION

Metallographic examinations were made on sections taken from the same eight assemblies that were employed in the hardness surveys. Each specimen was photographed at a magnification of $2^1/_4$ diameters to give the general appearance. Local areas on each specimen were also photographed at higher magnifications to ascertain the structural characteristics of the base materials, the weld deposit and heat effect from the two welding processes, with the varying carbon contents. Eight macrographs and nineteen photomicrographs in all were taken, but only a few have been selected for illustrations. These are shown in Figs. 11, 12 and 13. Microscopic examinations of the gas and arc welds revealed sound deposited metals with good fusion between weld metals and both fittings and pipe, as shown by the gradual merging of the weld deposits with the parent materials. In comparing Figs. 11 and 12, it will be observed that the heat effect produced by the oxyacetylene process is more pronounced than with the electric arc, extending further from the weld, and resulting in coarser structures in the adjacent parent metals. Although coarse grains of this type are usually considered to have somewhat lower physical properties and toughness, these have not been reduced materially as evidenced by the bursting and tensile pull tests made on the welded joints, wherein the failures occurred at points quite remote from the heat-affected zones. The effect of increased amounts of carbon in the parent metal on the grain size of the heat-affected adjacent metal is brought out in comparing Figs. 12 and 13. It is interesting to note the difference in structures between 0.13 and 0.35% carbon steel pipe.

## FATIGUE TESTS

A number of socket type, fillet-welded joints were made up with gas and arc welds, using $^3/_4$-inch tees, standard and extra strong pipe in both Grades *A* and *B*. They were subjected to fatigue tests in comparison with screwed joints in extra strong Grades *A* and *B* pipe, the tees being made from socket type forgings. These studies were made on a resonant magnetic fatigue-testing machine, in which the fittings were firmly fixed to a solid member and the pipe joined to the fittings, vibrated

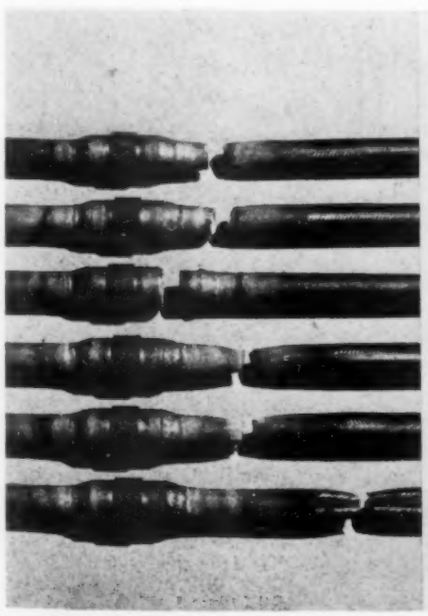


Fig. 8—Tensile Failures of 1-Inch Assemblies Having Sockets and Pipe of Equal Transverse Area

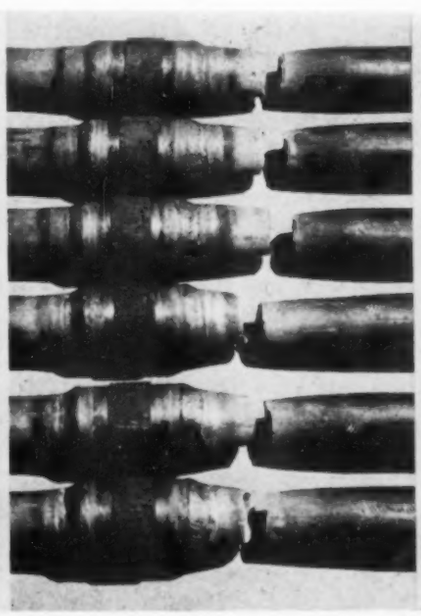


Fig. 9—Tensile Failures of 2-Inch Assemblies Having Sockets and Pipe of Equal Thickness

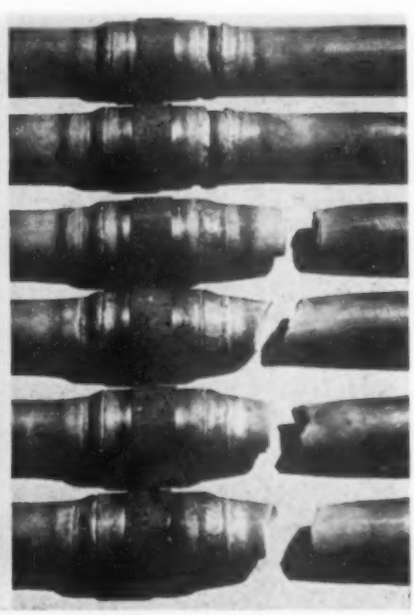


Fig. 10—Tensile Failures of 2-Inch Assemblies Having Sockets and Pipe of Equal Transverse Area

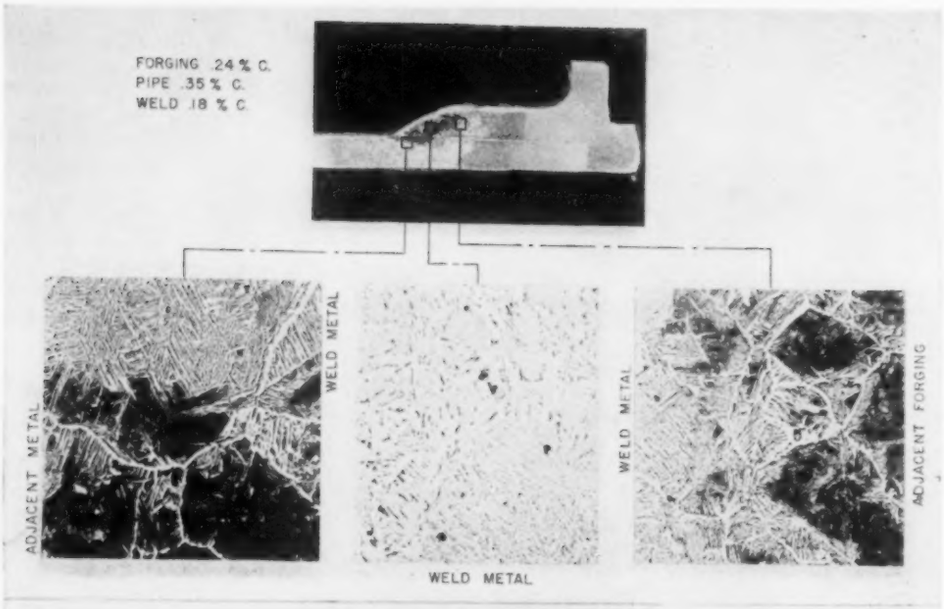



Fig. 11—Oxyacetylene Weld in Medium Carbon Steel Pipe 60 X

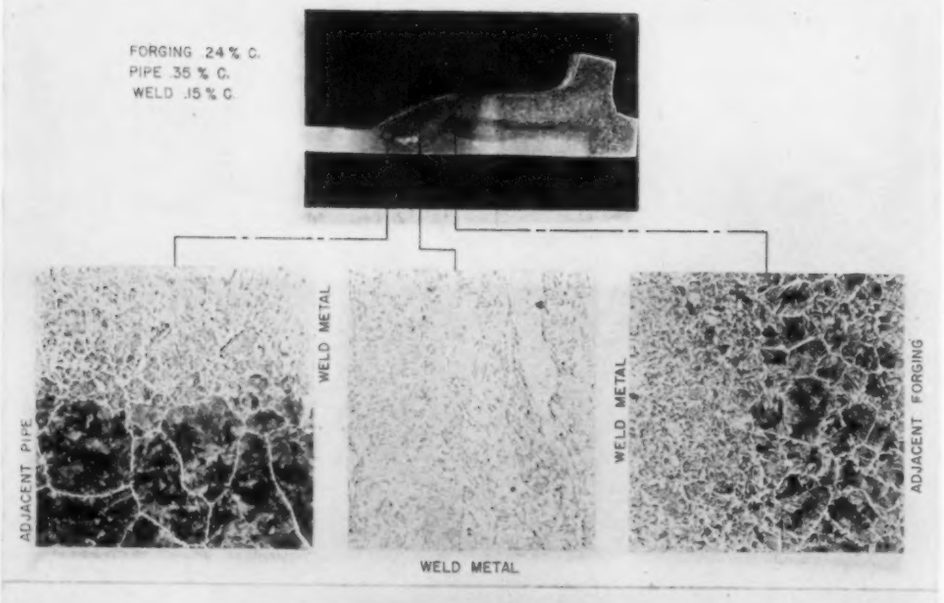



Fig. 12—Electric-Arc Weld in Medium Carbon Steel Pipe 60 X

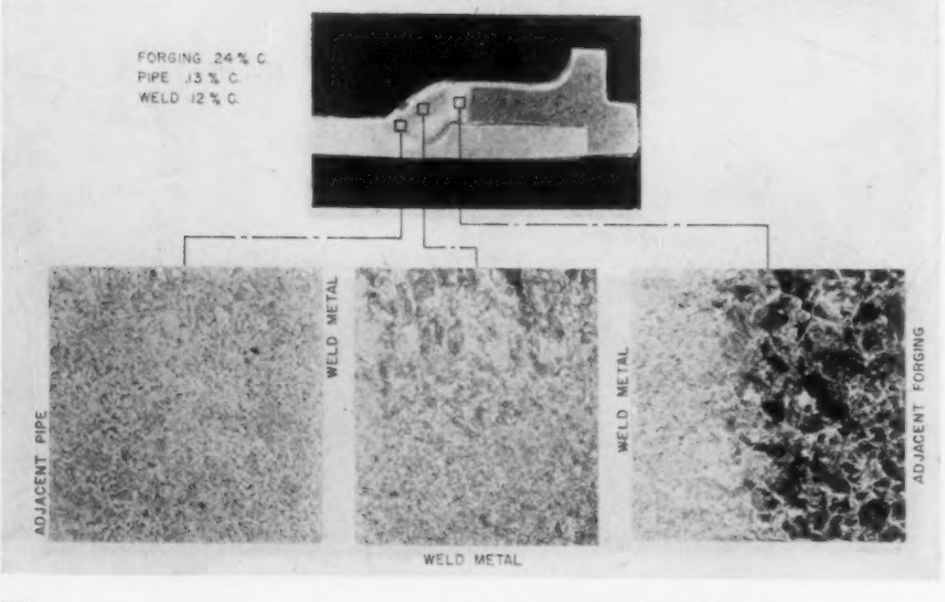
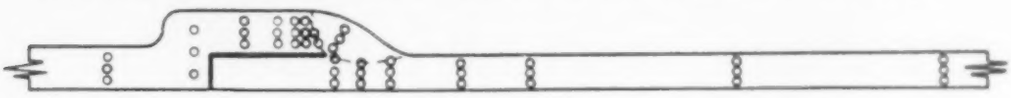



Fig. 13—Electric-Arc Weld in Low Carbon Steel Pipe 60 X

Table 5—Hardness Survey of Fillet Welds on 1 In. Tees and Grade "A" and "B" Pipe



Vickers Pyramidal Hardness Numbers at 30 Kilo-gram Load

| GRADE OF PIPE | TYPE OF WELD | TEE | | | | | | | | PIPE | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DISTANCE FROM FUSION LINE | | | | | | FUSION LINE | WELD | FUSION LINE | DISTANCE FROM FUSION LINE | | | DISTANCE FROM WELD | | |
| | | 1 1/2" | 7/8" | 1/2" | 1/4" | 1/8" | 1/16" | | | | 1/16" | 1/8" | 1/2" | 1" | 2 1/2" | 4" |
| Standard | Arc | 160 | 159 | 156 | 160 | 174 | 181 | 188 | 184 | 178 | 147 | 142 | 132 | 126 | 130 | 130 |
| Grade A | Gas | 169 | 150 | 153 | 153 | 159 | 171 | 161 | 146 | 141 | 132 | 133 | 128 | 123 | 124 | 123 |
| Standard | Arc | 160 | 163 | 159 | 169 | 174 | 186 | 192 | 189 | 222 | 251 | 249 | 202 | 201 | 201 | 197 |
| Grade B | Gas | 169 | 160 | 162 | 170 | 175 | 179 | 165 | 150 | 177 | 228 | 240 | 195 | 180 | 195 | 199 |
| Extra Strong | Arc | 158 | 160 | 160 | 164 | 185 | 195 | 212 | 182 | 160 | 150 | 145 | 131 | 129 | 129 | 131 |
| Grade A | Gas | 148 | 150 | 155 | 164 | 173 | 186 | 175 | 162 | 143 | 146 | 140 | 130 | 132 | 132 | 130 |
| Extra Strong | Arc | 158 | 157 | 160 | 163 | 181 | 196 | 187 | 179 | 207 | 200 | 189 | 177 | 168 | 175 | 170 |
| Grade B | Gas | 148 | 152 | 159 | 166 | 183 | 186 | 184 | 163 | 183 | 192 | 182 | 164 | 162 | 172 | 175 |

*Figures are an average of 3 readings.

by means of a strong electromagnet located at such a distance as to impose high stress reversals on the joints at each current cycle (see Fig. 14). Our findings reported herein cover only the preliminary investigation in which the pipe was vibrated at an amplitude to produce a stress in the pipe at the joint approaching the yield point of the material. At the present time further tests are being made with numerous improvements in the testing machine, which will permit more accurate control and greater range of stresses. Consequently, these results are only indicative and should not be construed as conclusive.

Failure always occurred as a minute transverse crack in the pipe at the edge of the weld and usually started at an irregularity in the weld contour, such as a ripple in the surface of the weld or in a slight undercutting of the pipe, all of which were points of stress concentration. It was observed that gas welds, because of their smoother contours, had a fatigue life almost double that of arc welds under the same stress conditions. It was also noted that gas welds having an approach angle of 30° with the pipe were somewhat superior to those made with a 45° angle, displaying approximately 20% advantage. This difference was not so noticeable in arc welds and apparently was due to ripples causing notch effects. Another interesting observation was that both arc and gas welds with extra strong Grade *A* pipe lasted seventeen times longer than screwed joints in the same pipe and 23 times longer than Grade *B* pipe.

It is generally accepted that the coarse-grained structures as displayed in Fig. 11 have lower endurance limits but this does not appear to be an important factor, as our findings indicate that smoothness and proper weld contour influence the fatigue life to an even greater extent than the metal itself.

## STRESSES IN WELDS DUE TO SHRINKAGE

Both the Code for Pressure Piping and the revised Paragraph P-112 of the A. S. M. E. Boiler Code recommend that a $^1/_{16}$-inch clearance be provided between the end of the pipe inserted into the socket bore and the shoulder in the socket, prior to welding to reduce the residual stress in the weld, resulting from shrinkage upon cooling from the welding heat. This clearance is not always possible to control and the question was therefore asked: if the pipe should shoulder, what would the stress be? The determination of stresses in welds is quite a controversial subject on which only brief progress has been achieved due to difficulties involved in making accurate strain measurements. Consequently, very little information is available that can really be applied to practical problems. Nevertheless, we made numerous attempts to measure stresses, and although we only achieved some degree of success, the indications were that the stresses due to shouldering are not of any consequence, as a certain amount of upsetting occurs in both the weld and adjacent metals while in the plastic range.

With reference to the original tensile pull tests, in which the joints were welded with the pipes in the ver-

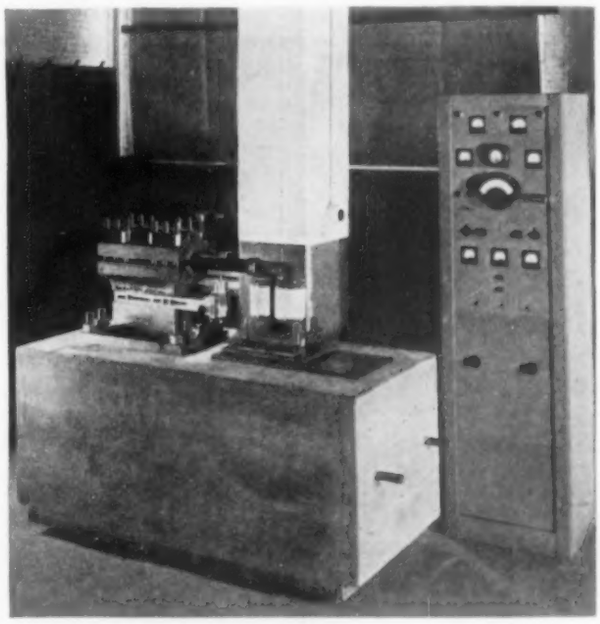


Fig. 14—Fatigue Testing Machine Used in Tests on Fillet-Welded Joints

tical position so as to shoulder in the recess of the fittings, failures occurred in every instance in the pipe. Had the shrinkage stresses in the weld, due to restraint, been of substantial magnitude, some failures would likely have occurred in the welds. Other examples of restraining forces occurring during welding are to be found in slip-on fillet-welding flanges and screwed-on flanges that are back or seal welded. In the case of the slip-on flange, the pipe is fixed after the first weld is completed, and, likewise, in the case of the screwed-on flange, the pipe is fixed by the threaded pipe connection. To our knowledge, welds on such flanges have never failed in service.

## SUMMARY

It can be said from the results of this investigation that fillet welds, as applied to piping, display excellent strength characteristics and can safely be employed in the same manner as butt welds, without any restrictions as to pressure and temperature. It is gratifying to know that Codes are recognizing this fact, making possible further application of fusion welding, and thus overcoming difficulties usually encountered in butt welding of the smaller sizes of piping.

## ACKNOWLEDGMENTS

The authors wish to express their appreciation for the metallographic work performed by Mr. W. L. Meinhart, Metallurgical Engineer in the Crane Research Laboratories.

# Tentative German Oxygen Cutting Standards*

EXISTING German standards for machined surfaces do not take into account the high state of oxygen cutting at the present time. Oxygen cut surfaces are not far behind good machine cut surfaces in smoothness, and precise tolerances can be met. Three types of cuts are recognized: (1) rough cut, (2) smooth cut, (3) dimensional cut. The rough cut generally is made by hand and numerical requirements are not imposed. The smooth cut is made by oxygen cutting machine (see Table 1 for tolerances). The cut is as smooth as a cut made on a planer or a milling machine. The dimensional cut is as smooth as the smooth cut, but must meet the tolerances in Table 1. A maximum deviation from a straight line of +0.04 inch is allowed for long straight cuts, not including bevel cuts.

* Translation of "Brennschneiden von Stahl; Begriffe, Verfahren, Zeichen" (Oxygen Cutting of Steel; Terms, Methods, Symbols), German Tentative Standard DIN 2310, sponsored by German Welding Research Committee of VDI, published in *Maschinenbau*, **23** (7), 317-318, July 1940.

**Fig. 1—Symbols for Oxygen Cutting**
Left: Rough cut (manual)
Middle: Smooth cut (machine)
Right: Dimensional cut

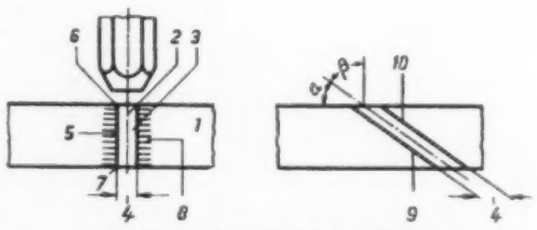



**Fig. 2—Terminology of Oxygen Cutting**
Left: Perpendicular Cut
Right: Bevel Cut

| | | |
|---|---|---|
| α = angle of cut | 3 = kerf | 7 = lower edge |
| β = angle of bevel | 4 = width of kerf | 8 = heat-affected zone |
| 1 = base metal | 5 = surface of cut | 9 = lower cut surface |
| 2 = axis of cut | 6 = upper edge | 10 = upper cut surface |

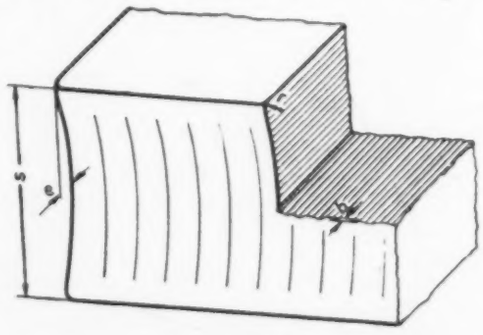



**Fig. 3**

The symbols used for the cuts are shown in Fig. 1, while the terminology of oxygen cutting is explained in Fig. 2. Cut edges and surfaces must be free from cracks and pronounced drag lines. Slag on the lower side must be easy to remove.

**Table 1—Maximum Allowable Dimensional Deviations, Inches, in Oxygen Cutting**

| Type of Cut | $V$* | $h$* | $e$* | Deviations for Different Lengths of Cut, In. Up to 4 In. | Over 4 to 20 In. | Over 20 to 40 In. | Over 40 In. |
|---|---|---|---|---|---|---|---|
| Smooth | 0.004+ 0.0012$T$ | 0.004+ 0.0004$T$ | 0.004+ 0.0008$T$ | ... | .... | .... | .... |
| Dimensional | 0.004+ 0.012$T$ | 0.004+ 0.0004$T$ | 0.004+ 0.0008$T$ | ±0.02 | ±0.04 | ±0.06 | ±0.08 |

$T$ = thickness, inches. The table applies to plates 0.16 to 4 inches thick.
* See Fig. 3. All dimensions are related to the edge of the cut, not to the center of the kerf.

# Reclaiming Spindles, Crabs, and Coupling Boxes

By D. B. RICE*

THE problem of reclaiming or replacing the wear on these items of steel mill rolling equipment has always been one of major proportions. Replacement cost of the parts would justify the necessary expenditures for reclamation if the equivalent to original wear were obtained. When increased service life is secured from the built-up part, an appreciable saving of maintenance man-hours and an increased production are accomplished.

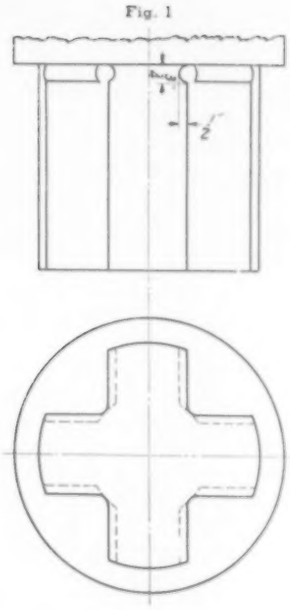
The spindles, crabs and coupling boxes, acting as the means of power transmission between the engines or motors, and the rolls, are subjected to extremely severe service. On a continuous type mill the pounding results in wear on one side of the pods only, while on the reversing mill both sides of the pods are active, and the effect is, therefore, doubly pronounced. The efficiency of the mill is materially reduced by wear at these points and frequent replacement is required either with new material or reclaimed parts to maintain the equipment within practical limits. Improper maintenance of separators or stretcher blocks very often causes excessive wear, which would ordinarily result in scrapping of the part as being too badly worn for reasonable reclamation. However, by the use of suitable welding materials for the purpose, even badly worn pieces can be reclaimed with the assurance that the additional service to be obtained will offset the expense and actual profit will be derived from it.

The following procedure, developed in one of the larger eastern steel plants, has resulted in several times the service to be obtained from new parts.

A number of analyses of steel are used for spindles and crabs. Predominant in this field, however, are carbon steels ranging from 0.45 to 55% carbon and the usual 12 to 14% manganese, or Hadfield steel.

* Welding Engineer, American Manganese Steel Division, Chicago Heights, Ill.

Fig. 1



It is sometimes necessary to replace as much as $1^1/_2$ inches of worn-away material on the sides of the pods and under such conditions there is some variation of materials used if the parts are of 0.45 to 0.55% carbon steel. Considering this type of steel first, all spalled or loose metal is removed from the areas to be built up. This is accomplished by means of a cutting torch or by chipping and grinding. The piece is then preheated to a temperature between 400 and 500° F. A carbon steel rod of comparable analysis is used to make the initial deposit and build up these areas to within $^1/_2$ inch of the finished surface. Each bead must be peened as applied to stress relieve and produce a more dense deposit, thus making the material less susceptible to flow under impact. The additional material needed to complete the build-up to template size is applied with electrodes of nickel-manganese steel, containing $3^1/_2$ to 4% nickel and 14% manganese, with 0.75 to 0.90% carbon. It is essential that each bead of the nickel-manganese deposit

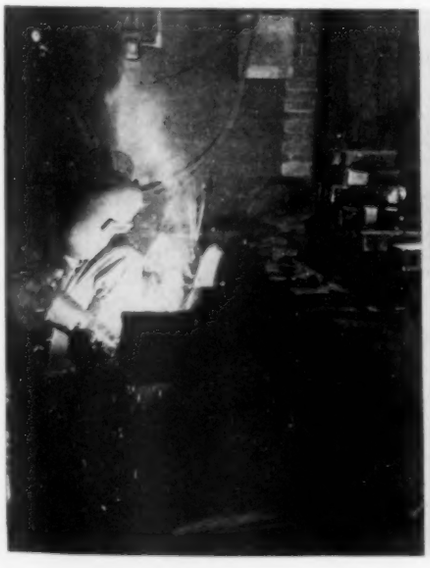


Fig. 2

Fig. 3

Fig. 4

be thoroughly peened not only for stress-relief, but also to increase the Brinell hardness of the deposited metal toward its ultimate hardness, which is between 400 and 450 Brinell. This operation, it was found, reduces the initial flow of the deposit in service and produces a much smoother finished surface. Any high spots should be removed with a hand grinder when welding has been completed so that all surfaces conform closely to the template. As a measure of precaution to prevent spalling in service, a dovetail or groove should be provided at the back of each pod to allow for any stretch or flow of the weld metal which may take place. This groove should be about $^3/_4$ inch wide and $^1/_2$ inch deep, as indicated on the sketch (Fig. 1).

In case the part is of the Hadfield or 14% manganese steel analysis, loose or spalled material is removed by grinding. Preheat temperatures must be limited to 300° F., as prolonged heating at temperatures above 400° has a detrimental effect on the physical properties of 14% manganese steel. Heating, however, does not affect nickel-manganese steel. The entire build-up is then made with nickel-manganese steel electrodes, as described.

Figure 2 shows a welder in action and the subject of his activities is a typical spindle or crab. Templates are used to check dimensions of the finished product. In Fig. 4, the subject is a coupling box of standard type and the welder is building it up to normal inside dimensions. Figure 3 indicates the excessive wear that takes place on these parts and details of the built-up areas.

The procedure for reclaiming of coupling boxes follows that of the spindles and crabs in so far as preparation, preheating and general welding practice is concerned. The initial build-up material, however, should be nickel-manganese steel, which is applied to within $^1/_4$ inch of finish dimensions. As all deposits are made on the interior of the casting, peening is difficult and the effects of it, in increased hardness of the material deposited, are not as great. To compensate for this condition and also to provide a metal of different analysis and characteristics to work opposite the nickel-manganese applied to the spindles, the final $^1/_4$ inch to reach finish dimensions should be deposited with a hard facing welding rod. A coating of tough, impact and abrasion resistant material, having a Brinell hardness between 450 and 500 as deposited, will thus be provided where the wear and impact are greatest. This hard face will furnish a dense, smooth deposit free from porosity or other defects and will require very little grinding to produce a surface sufficiently smooth and close to dimensions to be advantageous from a standpoint of wear and adequate bearing.

There is definitely an appreciable saving in maintenance costs to be made in reclamation work of this nature. The procedures detailed above have been tested and proved to accomplish such results.

# Light Sections for Spot Welding*

TWELVE tentative German standards have appeared for light steel sections for spot welding, Fig. 1. Their application is illustrated in Fig. 2. Trough sections are suitable for spot welding to walls as stiffeners. They also can be converted to hollow sections by spot welding small sheets across the opening. The flanges are sufficiently wide for spot welding.

* Tentative Standards E6751 to E6762, described on page 271 of Maschinenbau, 23, June 1940, p. 271–274.

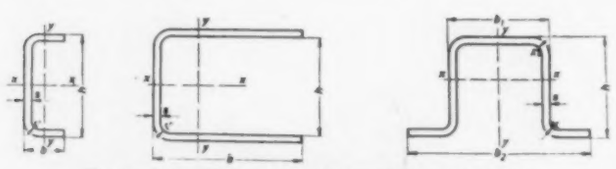


**Fig. 1—Left: U-Section with Small Flanges (E6761)**

$r$ varies from 0.039 to 0.16 in.
$h$ varies from 1.2 to 5.5 in.
$b$ varies from 0.47 to 0.71 in.
$s$ varies from 0.039 to 0.16 in.

**Middle: Wide "Open Box" Section (E6760)**

The sections vary from $h$ = 1.2, $b$ = 1.7, $s$ = 0.039 in. to $h$ = 5.5, $b$ = 6.4, $s$ = 0.16 in. The latter section weighs 9$^3/_4$ lb./ft. and the section modulus about the $y$ axis is 31.4 in.$^3$

**Right: Wide "Trough" Section (E6758)**

$h$ and $b_1$ vary from 1.2 to 5.5 in.
$b_2$ varies from 2.1 to 6.9 in.
$s$ varies from 0.039 to 0.16 in.

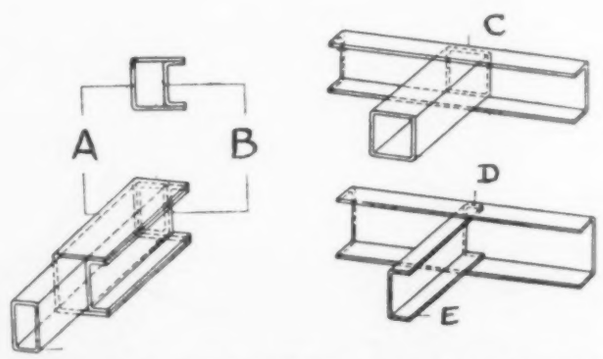



**Fig. 2—Left: U-Section with Small U Flange *B*, and Small "Open Box" Section B Spot Welded to Form a Reinforcement Over a Standard German Hollow Section**

**Upper Right: A Square Hollow Section Spot Welded at Right Angles to a Narrow "Open Box" Section *C***

**Lower Right: A Standard Channel *E* Spot Welded to a Narrow "Open Box" Section *D***

The "open box" sections are intended for conversion into new types of sections, especially hollow sections, by spot welding, Fig. 2. The dimensions of the "open box" sections permit them to be slipped over standard hollow, *C*, and *U* sections. The flanges are wide enough for only a single row of spot welds. These light steel sections were proposed in 1939 for agricultural machinery, but subsequently have been adopted in other industries. The sections are supplied in mild steel and high tensile steels (tensile strengths = 53,000 and 71,000 lb./in.$^2$, respectively).

# RECORDERS AND INDICATORS for Resistance Welding Machines*

By W. C. HUTCHINS†

OUT of 50,000 resistance welding machines, less than one per cent are equipped with any sort of instrument to inform the operator if variations occur in those factors which must be held constant for consistently strong welds. Fortunately the process lends itself to the juggling of many variables to arrive at a weld which is considered to be satisfactory—frequently "satisfactory welding" means that out of every four "welds" there are one or two "strong welds."

I know of one large corporation which until a year or so ago used spot welding only to hold the sheet metal parts together until they could be soldered or riveted. Soldering and riveting were used, according to the plant manager, because "we cannot depend on spot welding." Investigation showed that there were no data in the plant as to the current value, the duration of current, electrode pressure and electrode diameter required for any one job. Line voltage drift and its effect on the weld quality had been given no consideration. The operation of each welding machine was left entirely up to the operator who was given a foot-operated welder with which to guess at the timing, pressure and tap setting he should use for each weld—this to be done after he finished filing the electrodes to the shape he thought best for the job.

I do not intend to include in this paper instructions as to how consistently strong welds can be made but rather to describe a number of instruments for use with spot welders (some of which may be used with all types) which when used properly eliminate guess work and put resistance welding on a scientific basis—a fabricating process that is just as dependable as riveting, fusion welding or any other form of fabrication. Such scientific use of resistance welding permits the manufacturer to take advantage of the many benefits to be realized through its proper use—each weld designed to take a prescribed load.

A description of various instruments follows or where these devices are known to have been previously published, references will be given.

## MEASUREMENT OF CURRENT

The heat produced in a spot or seam weld is proportional to the square of the current, if all other variables remain constant. It is obvious, therefore, that the value of current must be known before one can complete the electrical specification for a weld.

The following devices are used for the measurement of current in the resistance welding circuit.

1. Electromagnetic oscillograph with primary or secondary shunt.
2. Current crest meter.
3. Cathode-ray oscillograph with primary shunt.
4. Pointer stop ammeter with primary clamp on current transformer.
5. Vacuum-tube voltmeter with secondary current transformer.
6. Neon-tube meter with secondary toroid.

These devices are individually discussed in a paper by Dr. W. F. Hess entitled, "The Measurement of Spot Welding Current," *Electrical Journal* (*Transactions*), June 1940.

The pointer stop ammeters (also pointer stop voltmeters) are described in more detail in THE WELDING JOURNAL, March 1940.

The magnetic oscillograph is almost indispensable in fundamental research work, in that it is the most flexible of instruments available. It permits the study of transient phenomena and permits simultaneous readings of many functions, so that the relation between them and how they affect the quality of welds can be studied. For instance, an oscillogram of one operation of a spot welding machine can be made to disclose the following information simultaneously:

The wave form, duration and value of current, in both the primary and secondary circuits.
Electrode to sheet resistance.
Sheet to sheet resistance.
Voltage, power factor and watts input to the welding machine. (See "Studies of Spot Welding of Low Carbon and Stainless Steels," THE WELDING JOURNAL, October 1938.)

## MEASUREMENT OF VOLTAGE

The voltage of a system is relatively unimportant except as it affects the value of current which flows. The current varies directly with the voltage. It is, of course, necessary at times to check the voltage of the primary and also the voltage of the secondary of the welding machines, especially during the manufacturing and testing of welding equipment. The measurement of the voltage, while making a weld, is frequently a method whereby difficulties caused by current variation, can be analyzed. It may be found that the current varies considerably from one weld to the next. Immediately one can determine whether or not the primary supply voltage variation is causing the trouble by measuring the voltage during the weld. Low current produces low heat and low voltage may be causing erratic operation of the control. The magnetic oscillograph is probably the

* Presented at the Annual Meeting, A. W. S., Cleveland, Ohio, October 23, 1940.
† Industrial Department, General Electric Company.

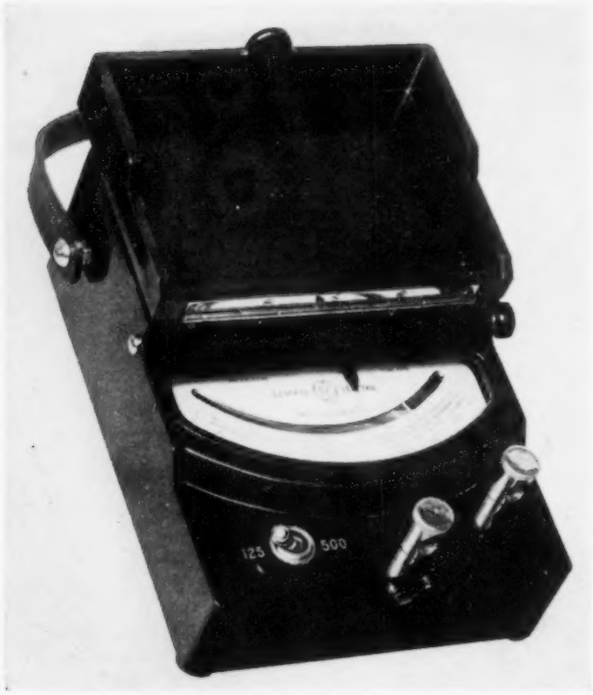



Fig. 1—Portable Pointer Stop Ammeter

most accurate method of measuring voltage, but its use may not be justified in many cases. The conventional voltmeter cannot be used accurately for this purpose because the duration of the weld is so short that the conventional instrument, having a period of one or two seconds, will not reach a stable position before the weld is completed. A simple method, accurate within three to five per cent, is to use a pointer stop voltmeter similar to that of the pointer stop ammeter for measuring current, except that the stop is on the high side of the needle or pointer. The pointer is pushed down scale until it does not drop away from the stop during the time a weld is made, thus the voltage during the weld is indicated.

## MEASUREMENT OF TIME (DURATION OF CURRENT FLOW)

In addition to the oscillograph there are a number of instruments available for determining the duration of current flow, for instance, the cycle recorder. The cycle recorder consists of a frequency-sensitive element, on the end of which is a stylus. The stylus makes a trace on a narrow strip of paper. This paper strip travels at the rate of several inches per second while a record is being taken. When connected across the primary of the resistance welding machine or used with an exploring coil suspended in the secondary circuit of the welder transformer, the trace is a straight line except when power is applied to the primary of the welding machine. During the interval that current flows, the 60-cycle current will cause the recorder to trace this alternating current. Each half-cycle can be counted to determine the number of half-cycles that current was applied to the welding machine. A detailed description of this cycle recorder appears in the *General Electric Review*, August 1935.

## WELD RECORDER OR AMPERE SQUARED SECOND RECORDER

Probably the most wanted instrument today in the resistance welding field is an instrument which will positively and accurately inform the operator when any variation occurs which will reduce the strength of a weld below a predetermined minimum, and simultaneously record the per cent reduction in strength of that weld.

The nearest approach to the "most wanted instrument today" is probably the so-called weld recorder.

The weld recorder is a recording instrument, signaling device, and lockout control that records on a paper chart the variations of the electric input for each spot weld as compared with the input for other welds, and as compared with a predetermined normal.

It is so designed that when a variation of $I^2t$ occurs which may be of sufficient magnitude to cause a poor weld (based on the predetermined settings of the recorder) a bell gives a continuous audible signal and the weld-initiating circuit is automatically opened, preventing subsequent welding until a push button is pressed. In addition, the recorder chart indicates visually that the weld was not within the preset allowable limits for proper welding and shows whether the input was above or below normal.

The enclosing case can be locked, so that only an authorized person can start the welding machine after a stoppage due to input variations outside the preset limits.

It may be asked, since billions of spot welds have been made in the past without the use of recorders, why should they now be used? The answer is easy. Users' specifications are becoming more stringent because spot welding is now being used in making aircraft, rail cars, buses, trucks and trailers. These structures are subjected to pulsating stresses, and failures of welds may be serious.

### *Variables in Resistance Welding*

The following are the variables which must be accurately controlled to obtain high-quality welds:

1. Electrodes (dimensions, material, contact surface and cooling).
2. Pressure of the electrodes on the parts to be welded.
3. Surface and character of the metal to be welded.
4. Value of the current.
5. Character of the current wave for each weld.
6. Timing of current for each weld.

The heat developed in the weld zone is proportional to the square of the current ($I$) and varies directly with the time ($t$) of current application and the resistance ($r$) of the weld zone. The heat produced is, therefore, proportional to $I^2rt$.

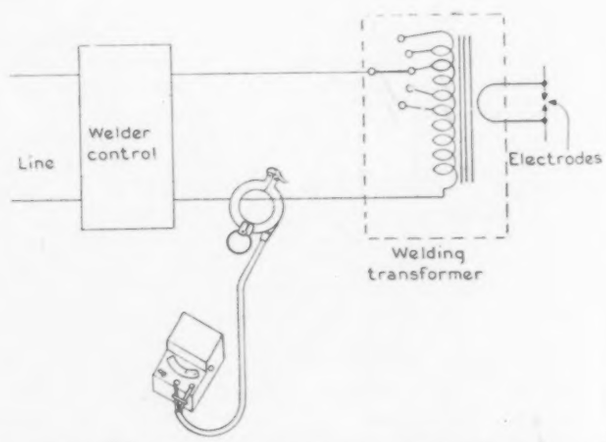



Fig. 2—Schematic Diagram—Measurement of Welder Current with Split-Core Transformer and Pointer Stop Ammeter

Of the three items, resistance ($r$) varies by a negligible amount from one weld to another on metal of the same analysis and gage, if the electrode pressure is consistent, if the shape of the electrode tip is properly maintained, and if the contact surfaces in the weld zone are uniformly clean. Under reasonable procedure and inspection, the resistance just before making welds may be assumed to be sufficiently constant for all practical purposes. If the resistance remains constant, the heat produced in the spot weld is proportional to $I^2t$, the current variation and the timing variation probably having the greatest effect on the soundness of the welds. The weld recorder has been so designed that its deflection (ultimate position) is proportional to $I^2t$; thus, it is an accurate check on the electric input to the welding machine.

Though time ($t$) is constant for a given setting of synchronous timers, such as thyratron controls, it may vary considerably when timers employing contactors are used.

The remaining variable, current ($I$), is beyond the control of the operator. The major causes of its variation are changes in the voltage impressed upon the primary side of the welding transformer, changes in the impedance of the transformer and the secondary leads to the welding tools, poor contacts in the secondary circuit and transient current variation resulting from starting current flow at different points on the voltage wave from one weld to another.

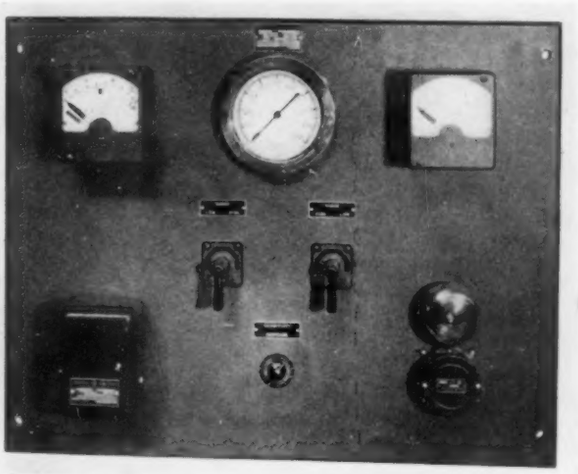
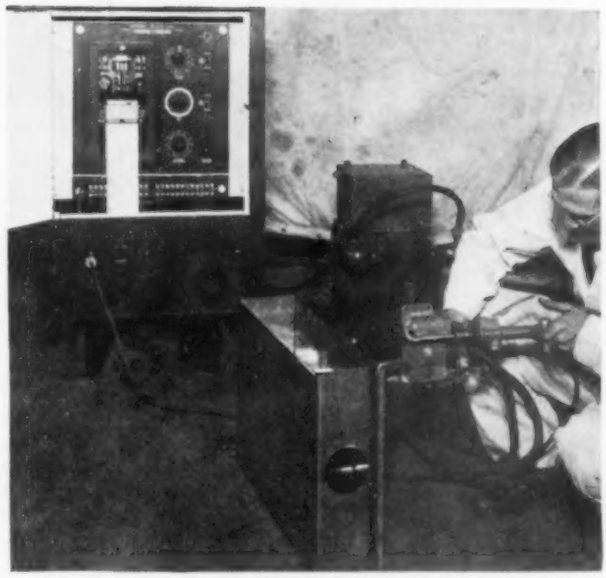


**Fig. 3—Ampere-Second Consistency Panel Mounting, Also a Pressure Gage and Conventional Ammeter**

Since the heat in the weld zone is proportional to the square of the current (assuming the resistance remains constant), a current increase of 15 per cent will cause a welding-heat increase of 32 per cent. Current is the variable to which the welding heat is most sensitive—since it enters as the square in the heat formula—yet its variations are beyond the control of the operator.

The movement of the pointer of the weld recorder is directly proportional to $I^2t$. It is, therefore, a valuable aid, for with its use the operator of the welding machine is informed if the value of the current, character of the current wave or time of current flow changes to such an extent that $I^2t$ varies outside the preset allowable limits.

Variations in electrode dimensions, contact-surface conditions, electrode pressure and character of the metal to be welded should be eliminated by supervision of the welding process, as far as is possible, because they influence weld quality. These variations usually have slight effect on the current and, therefore, will not result in an appreciable change in $I^2t$. However, if such variations are of sufficient magnitude to affect the value of the current, the change in $I^2t$ will be accurately recorded.



*Courtesy Edward G. Budd Mfg. Co., Philadelphia, Pa.*

**Fig. 4—Weld-Recorder Panel, Mounted with Synchronous Thyratron Spot-Welder Control in a Portable Case**

This control is suitable for a separate welder transformer, large or small

## DESCRIPTION AND RATING

### *Recording Instrument*

The recording instrument is similar in appearance to a recording ammeter; however, the deflection is essentially proportional to $I^2t$, for current-flow intervals of $^1/_{60}$ of a second minimum to $^1/_2$ of a second maximum. With minor modifications it can be used with pulsation welding or spot welding, having current flow longer than $^1/_2$ second. The moving element is mounted on jewel

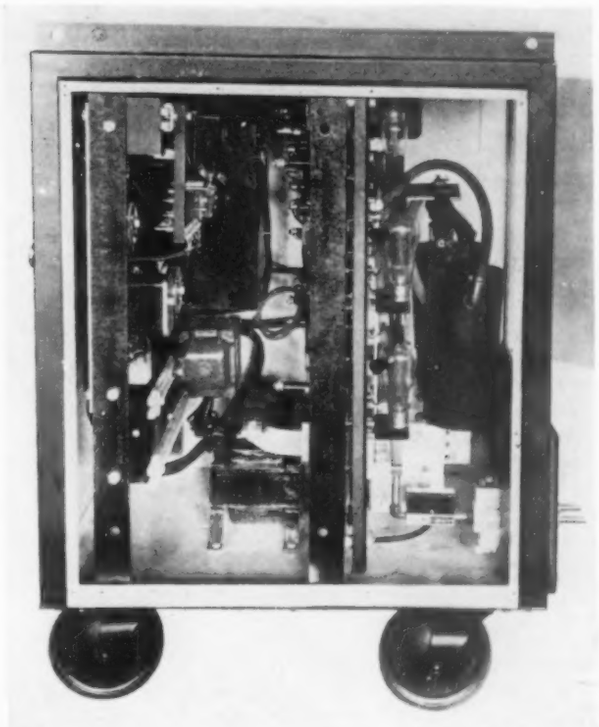


**Fig. 4A—Synchronous Control and Recorder Unit**

This side view of the portable unit shows the recorder panel at the left, the synchronous thyratron control with ignitron tubes at the right, and the current transformer for the recorder mounted on the floor of the cabinet

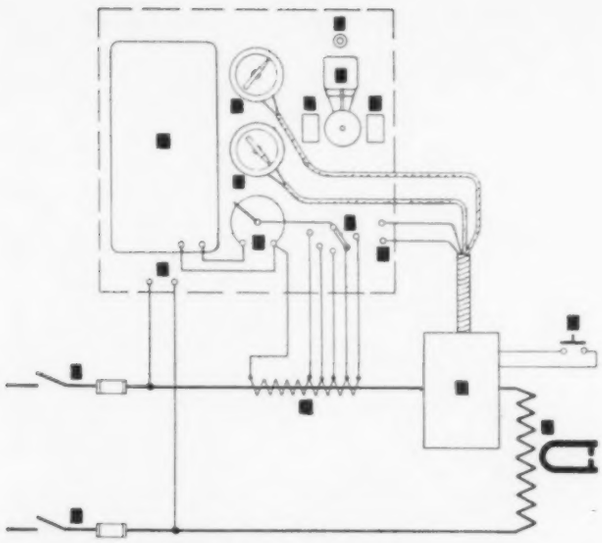


**Fig. 5—Connection Diagram of a Weld Recorder, Thyratron Synchronous Control and a Welding Machine**

*A*—$I^2t$ recording instrument; *B*—Push button to reset after excessive variation in $I^2t$; *C*—Relays; *D*—Time adjustment dial for welder control; *E*—Gong; *F*—Heat adjustment dial for welder control; *G*—Control power to recorder; *H*—Sensitivity control; *I*—Tap changing selector switch; *J*—Initiating circuit; *K*—Weld initiating switch; *L*—Air circuit breaker or safety switch; *M*—Current transformer; *N*—Thyratron welding control including synchronous timer; *O*—Welding transformer and welding machine

bearings and has no other mechanical restrictions to its movement; therefore, accuracy is assured.

The instrument pointer is motored up scale. The speed is proportional to the square of the current. When current flow ceases the pointer immediately stops. The record is made, without the use of fluid ink, on a 4-inch paper chart from a record roll which travels at a speed of 4 inches per minute, the paper chart passing over an inked ribbon. After the pointer of the instrument has swung to its final position for a given weld, a solenoid-operated bar strikes the pointer and makes a record in the form of a dot. The maximum and minimum preset allowable limits of $I^2t$ are also shown on the paper chart. Immediately after the record is made the pointer is motored back to the zero position to be quickly ready for another weld. Welds can be recorded up to 100 per minute.

The chart roll, which includes approximately 200 feet of paper, is automatically fed through the recorder for each weld.

The instrument is designed so that it must receive approximately 0.4 ampere-squared seconds for normal deflection (mid-point within the preset limits). To provide a means of using the recorder over a wide range of current and timing variations, a tapped current transformer, a tap-changing switch and a sensitivity control are used.

The tap-changing switch is used by the operator to select the tap on the current transformer that will provide approximately the correct current to the recorder for normal deflection (for the time setting that is being used). The sensitivity control consists of potentiometers. Normal deflection of the recorder can be established for the value of current and timing required to produce a satisfactory weld as determined by test. Once adjusted for a weld, the potentiometer and the tap switch remain unchanged for duplicate welds.

The limits of $I^2t$, outside which an improper operation of the welding machine will be recorded and audibly indicated, are plus or minus 15 per cent, which experience has proved to be practical. Plus or minus 15 per cent $I^2t$ corresponds to approximately $7\frac{1}{2}$ per cent voltage or current change or 15% timing change.

*The Recorder Panel*

Table 1 below shows practical operating speeds for the weld recorder for various durations of weld current. With a weld time of 1 cycle, a speed of 120 welds per minute has been obtained. For higher welding speeds (such as those required for seam welding) a simple selective device is placed in the circuit so that the recorder checks, say, one out of every ten current flow intervals.

**Table 1**

| Weld Duration in Cycles (1 Cycle = 1/60 Sec.) | Recommended Maximum Rate of Recording (Welds per Minute) |
|---|---|
| 1 to 5 | 100 |
| 10 | 80 |
| 20 | 65 |
| 24 | 60 |
| 30 | 55 |

The weld recorder has not yet been used with the stored energy spot welding machines; however, work on this problem is progressing.

The weld recorder can be used with synchronous electronic control or any known form of mechanical or magnetic control; however, with any control other than the precisely synchronous, variations in transient currents for conventional spot welds have proved to cause $I^2t$ to vary more than ±15%. With pulsation welding, the transients of non-synchronous control are cumulative and greater $I^2t$ variations will occur than with single spot welds. From this it is obvious that when a weld is

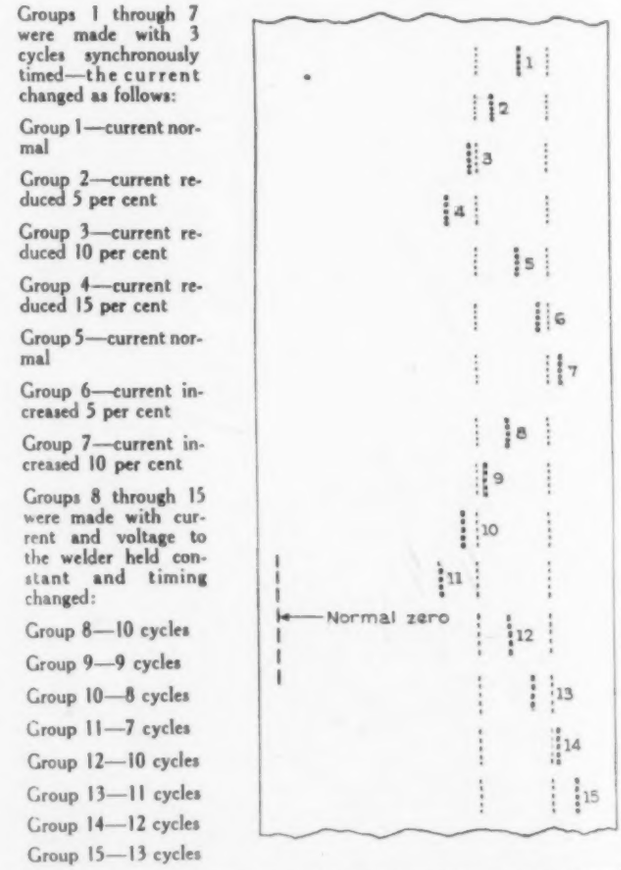



**Fig. 6—Tracing of a Record from the Weld Recorder One-Half Actual Size**

Five welds were made at each of the settings indicated at the left. Synchronous thyratron welder control was used

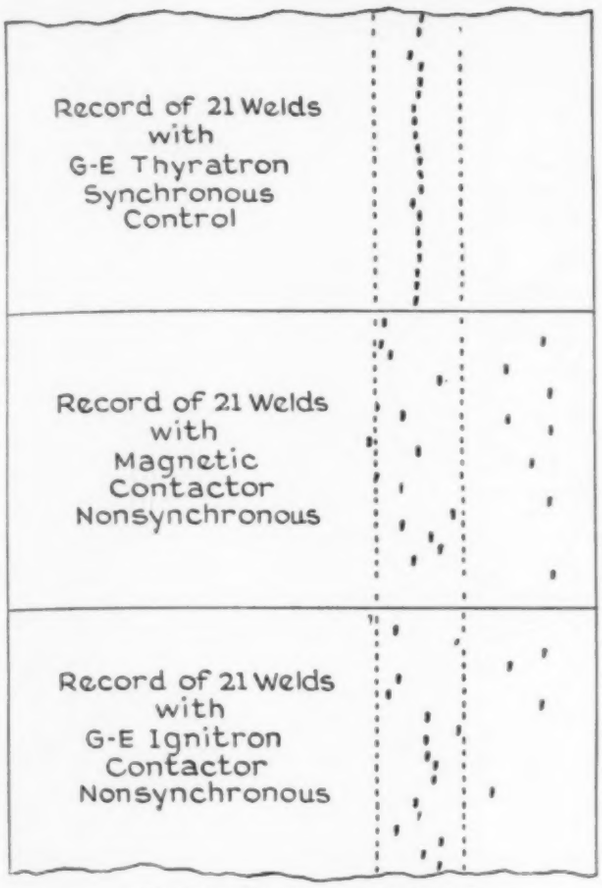

Record of 21 Welds with G-E Thyratron Synchronous Control
Record of 21 Welds with Magnetic Contactor Nonsynchronous
Record of 21 Welds with G-E Ignitron Contactor Nonsynchronous

**Fig. 7—Tracing of Weld-Recorder Record**

Each of the darker dots represents one weld. Welds were made with the types of control indicated at the left. The allowable limits of $I^2t$ (represented by parallel rows of dots) are adjusted for variation of plus or minus 15 per cent

to receive $I^2t$ within $\pm 15\%$, only precisely synchronous control should be used.

*Ampere-Second Consistency Indicator*

An indicating instrument of considerably lower cost than the recorder but intended for the same purpose (except without the recording and lockout feature) is the so-called Ampere-Second Consistency Indicator, consisting of a conventional switchboard type of ammeter modified to include a light source, mirror on the back of the pointer, and a phototube, all within the same instrument enclosing case. There also are included a relay which is operated by the phototube and the ammeter, a potentiometer with dial adjustment and a single stroke gong. The ammeter is connected to the secondary of a current transformer located in the primary of the resistance welding machine. Such an ammeter requires approximately one second for the instrument to reach a stable reading after a change of current flow. Because of the inertia of the moving parts of the instrument, the pointer of the ammeter will continue to travel across the dial after the current flow ceases, provided the duration of this current flow to the welding machine is in the range of, say, 1 to 15 cycles. The potentiometer permits adjustment of the instrument so that it will deflect to the mid-position for that current and timing which produces a good weld (as determined by tests). Since the products of current and time of current flow should be the same for each "best" weld, the ammeter will always deflect to the same mid-position for all welds receiving the desired or optimum ampere seconds.

The light source within the instrument projects a light out through a hole in the face of the instrument. When the ammeter deflects to the mid-position, the mirror on the back of the pointer reflects the light back through the hole on to the phototube. This light on the phototube actuates the relay which in turn causes a single stroke of the gong. Should the time or voltage (or both) change so as to deliver to the welding machine a reduced number of ampere-seconds, the gong will not strike, indicating insufficient ampere-seconds for best welding conditions.

Should the time or voltage (or both) change so as to deliver to the welding machine an increased number of ampere-seconds, the ammeter will swing past the mid-position, causing one stroke of the gong, and as the weld is completed and the ammeter swings back, the pointer crosses the mid-position a second time causing a second stroke of the gong. Double strokes of the gong indicate to the operator that excessive heat has been delivered to the weld.

This type of instrument gives an audible signal at any time that the voltage or current changes enough to throw ampere-seconds outside of certain limits which are approximately plus or minus 10 per cent. By changing the design of the mirror on the pointer the instrument can be made to give the operator a signal for a greater percentage such as 15 or 20 per cent.

A number of these equipments have been used by aircraft manufacturers. A typical panel is shown in Fig. 3 combining the ampere-second consistency indicator with an ammeter or voltmeter and a pressure gage, all on the same panel. The instrument having the photoelectric ammeter is shown in the upper left corner, as is obvious from the hole in the face of the instrument.

The maximum possible speed for this type of instrument is determined by the period of the instrument. If the instrument has a period of approximately two seconds, which is typical, the maximum speed will be such as to allow the instrument to swing up-scale and come to rest again at zero for each weld. This means approximately 25 to 30 welds per minute, absolute maximum.

The maximum duration of current flow is limited to approximately one-quarter to one-third the time required for the instrument to reach stable reading for a given current value. This means approximately 15- or 20-cycle maximum. When used for longer duration of current flow, the accuracy of the instrument is considerably reduced.

Welding engineers who take advantage of the benefits to be realized through the proper use of these instruments will show more consistent weld quality, fewer rejects and consequently lower manufacturing cost.

# CURRENT WELDING LITERATURE

Agricultural Machinery. Progressive Assembly. Steel, vol. 107, no. 11 (Sept. 9, 1940), pp. 58, 60, 62 and 72.

Airplane Design. Strength-Weight Ratio Is Improved by Steel Tubing, J. W. Greve. Machine Design, vol. 12, no. 1 (Jan. 1940), pp. 49–50.

Airplane Manufacture. Large-Scale Sub-Contracting, J. A. Oates, Aircraft Production, vol. 2, no. 2 (Feb. 1940), pp. 49–55.

Airplane Manufacture. Spot Welding Aircraft Materials, C. L. Hibert. Metal Industry (Lond.), vol. 56, no. 17 (April 26, 1940), pp. 371–375.

Airplane Manufacture. Spot Welded Aluminum Aircraft Structures, C. W. Dodge. Product Eng., vol. 11, no. 9 (Sept. 1940), pp. 388–392.

Airplane Manufacture. Stainless Steel in Aircraft, C. DeGanahl. Am. Mach., vol. 84, no. 15 (July 24, 1940), pp. 527–529.

Airplane Manufacture. Welding Aluminum Alloys. Aircraft Production, vol. 2, no. 7 (July 1940), pp. 234–235.

Airplane Manufacture. Welding in Aircraft Industry, L. P. Wood. Metal Industry (Lond.), vol. 57, no. 8 (Aug. 23, 1940), pp. 142–146.

Airplane Materials. Stainless Steel for Aircraft Structures, H. W. Perry, Aircraft Production, vol. 2, no. 2 (Feb. 1940), pp. 35–37.

Aluminum. Fluxes for Welding Aluminum, E. G. West. Inst. Welding—Trans., vol. 3, no. 2 (April 1940), pp. 93–105; see also Foundry Trade Journal, vol. 63, no. 1251 (Aug. 8, 1940), p. 88.

Automobile Fenders. Unique Practices in Producing Oldsmobile Front Fenders, C. O. Herb. Machinery (N. Y.), vol. 46, no. 12 (Aug. 1940), pp. 83–88.

Barges. Electric 21. Mar. News, vol. 27, no. 1 (June 1940), pp. 40–41.

Bearing Metals. Soft Soldering, Silver Brazing and Gas Welding of High Nickel-Bearing Alloys. Welding Engineer, vol. 25, no. 8 (Aug. 1940), pp. 30–33.

Bins. Low Cost Construction of Arc Welded Storage, W. J. Brooking. Mill & Factory, vol. 27, no. 2 (Aug. 1940), pp. 70–71 and 180.

Blast Furnaces. Welded Blast Furnace Stack, L. J. Gould. Iron & Steel Engr., vol. 17, no. 6 (June 1940), pp. 23–27, (discussion), 27–29.

Bridges, Highway. County Bridge Maintenance, L. W. Brunson. Roads & Streets, vol. 83, no. 8 (Aug. 1940), pp. 62, 64 and 68.

Bridge Piers. Steel Pile Bridge Piers on Canadian National Railways. Engineer, vol. 170, no. 4409 (July 12, 1940), pp. 20–23.

Bridges, Steel. Welded Rigid Frames, European Style, F. L. Plummer. Engrg. News-Record, vol. 125, no. 3 (July 18, 1940), pp. 91–93.

Buildings, Steel. Welding Cuts Cost of Air Lines Terminal, L. Grover. Engrg. News-Record, vol. 125 no. 3 (July 18, 1940), pp. 94–97.

Chains. Electric Welded Chain, A G. Anderson. Steel, vol. 106, no. 22 (May 27, 1940), pp. 70 72–73 and 80.

Clay Products Plants. Get Exactly the Die You Want by Welding—It Saves Time and Money Too, H H. Mansur. Brick & Clay Record, vol. 97, no. 2 (Aug. 1940), pp. 23–25.

Cleaning. Are You Spending Too Much Time and Effort on Cleaning Your Welds? R. Lattice. Welding Engineer vol. 25, no. 6 (June 1940), pp. 25–27 and 31.

Concrete Reinforcement. Shear Reinforcing for Concrete Beams, D. M. McCain. Steel, vol. 107, no. 3 (July 15, 1940), pp. 58–59 and 78–79.

Copper Silicon Alloys. Silicon Bronzes, H. Lawrence. Steel, vol. 106, no. 23 (June 3, 1940), pp. 67–68.

Costs. Cost-Finding for Welding Shop. Oxy-Acetylene Tips, vol. 19, no. 8 (Aug. 1940), pp. 173–176.

Defects. Repairing Defects in Welds, H. Lawrence, Steel, vo.. 107, no. 5 (July 29, 1940), pp. 64–65 and 72.

Diesel Engines. Diesel Engine Frames, M. Essl. Steel, vol. 106, no. 21 (May 20, 1940), pp. 72, 74 and 79.

Electric Welding, Arc. A. C. Welding Aids Metal Fabricator, L. D. Jennings. Iron Age, vol. 146, no. 6 (Aug. 8, 1940), pp. 40–41.

Electric Welding, Arc. Atomic Hydrogen, R. M. Fenton and E. W. Dougherty. Iron Age, vol. 146, no. 3 (July 18, 1940), pp. 40–42.

Electric Welding, Arc. Influence of Size on Fracture of Notched-Bar Test Pieces, B. P. Haigh. Engineering, vol. 149, no. 3878 (May 10, 1940), pp. 490–491.

Electric Welding. Current Distribution, H. Lawrence. Steel, vol. 107, no. 2 (July 8, 1940), pp. 56 and 59.

Electric Welding Machines. Economical Welding Machines at Work in Progressive Pacific Coast Shipyards. Pacific Marine Review, vol. 37, no. 7 (July 1940), pp. 48–49.

Electric Welding Machines. 6000 Welds per Hour. Steel, vol. 107, no. 8 (Aug. 19, 1940), pp. 72 and 79.

Electric Welding Machines. Spotwelding Machine Settings—And Their Effect on Weld Strength, A. M. Unger. Iron Age, vol. 145, no. 25 (June 20, 1940), pp. 27–31.

Electric Welding Machines. Multiple Spot Welding. Welding Engineer, vol. 25, no. 4 (April 1940), pp. 33–34.

Electric Welding Machines. What's New in Welding Apparatus, F. J. Oliver. Iron Age, vol. 145, no. 24 (June 13, 1940), pp. 45–50.

Electric Welding, Resistance. Controlled Spot Welding, H. Thomasson. Can. Metals & Met. Industries, vol. 3, no. 5 (May 1940), pp. 131–132.

Electric Welding, Resistance. Principles of Sciaky System of Stored Energy Spot Welding. Welding Engineer, vol. 25, no. 8 (Aug. 1940), pp. 19–24.

Electric Welding. Repair by Welding of Cast-Steel Hydraulic Cylinder. Engineering, vol. 149, no. 3878 (May 10, 1940), pp. 475–477, supp. plate.

Fillet Welds. Angular Distortion, C. H. Jennings. Steel, vol. 106, no. 24 (June 10, 1940), pp. 72 and 74.

Gasoline Engines. Stationary Internal Combustion Engines. Electric Welding, vol. 9, no. 50 (Feb. 1940), pp. 38–40.

Gears and Gearing Manufacture. Making Welded Gears, H. Menck. Steel, vol. 107, no. 1 (July 1, 1940), pp. 66–68.

Iron Castings. Low Temperature Welding of Cast Iron, H. Klopstock. Junior Institution Engrs. J. (July 1940), pp. 271–290; see also Machinery World, vol. 108, no. 2795 (July 26, 1940), p. 64–65.

Iron Castings. Welding of Cast Iron, L. Tibbenham. Iron Age, vol. 145, no. 26 (June 27, 1940), pp. 36–38.

Jigs and Fixtures. Welding in Jig Time, J. Haydock. American Machinist, vol. 84, no. 9 (May 1, 1940), pp. 277–279.

Joints. Modern Assembly Processes, J. L. Miller. Metal Industry (Lond.), vol. 57, nos. 3, 4, 5, 6, 7 and 8 (July 19, 1940), pp. 42–46, (July 26), pp. 65–66, (Aug. 2), pp. 82–86, (Aug. 9), pp. 109–111. (Aug. 16), pp. 124–127, and (Aug. 23), pp. 147–150.

Locomotive Axles. Fatigue Strength of Axles with Surfaces Metal Coated and Flame Hardened, O. J. Horger and T. V. Buckwalter. Heat Treating & Forging, vol. 26, no. 7 (July 1940), pp. 321–325 and 336.

Locomotive Fireboxes. Copper Welding for Locomotive Firebox Construction. W. Cook and E. Davis. Inst. Welding—Trans., vol. 3, no. 2 (April 1940), pp 109–112.

Locomotives, Freight. Problems of Freight-Car Weight Reduction, V. R. Willoughby. Railway Mech. Engr., vol. 114, no. 6 (June 1940), pp. 223–224.

Machinery Manufacture. Design and Welding of Fabricated Machinery, J. H. Cooper. Iron Age, vol. 145, nos. 23 and 24 (June 6, 1940), pp. 50–52 and (June 13), pp. 40–44.

Machinery Parts. Hard-Facing Machine Parts, C. H. S. Tupholme. Min. Mag. vol. 63, no. 2 (Aug. 1940), pp. 70–75.

Machine Tools. Modern Machine Tools. Aircraft Production, vol. 2, nos. 3, 4 and 5 (March 1940), pp. 97–99, (Apr.) pp. 119–121 and (May), pp. 169–171.

Materials Handling. Handling for Welding, H. Lawrence Steel, vol. 107, no. 6 (Aug. 5, 1940), pp. 48, 50 and 87.

Materials Testing Machines. New Equipment for Testing Fatigue Strength of Riveted and Welded Joints, W. Mueller. Nat. Advisory Committee Aeronautics—Tech. Memo, no. 947 (July 1940), 5 pp., supp. plates.

Metals. Analysis of Fundamental Factors of Hard-Facing Technique, T. B. Jefferson. Welding Engineer, vol. 25, no. 6 (June 1940), pp. 28–31.

Metals. Hard-Facing for Modernization, R. L. Lerch. Min. Congress J., vol. 26, no. 6 (June 1940), p. 16.

Motor Truck Manufacture. Body Design Gives Added Torsional Rigidity, H. C. Frentzel. Automotive Industries, vol. 83, no. 3 (Aug. 1, 1940), pp. 108–109.

Motor Truck Manufacture. Nothing but Welding, W. A. Salzmann American Machinist, vol. 84, no. 16 (Aug. 7, 1940), pp. 579–581.

Natural Gas Pipe Lines. Welding 24-Inch Natural Gas Line Sets Precedent, F. B. Taylor Oil Weekly, vol. 98, no. 11 (Aug. 19, 1940), pp. 42 and 44.

Natural Gas Wells. Laying Thick-Walled Lines for Recycling System. Oil Weekly, vol. 99, no 1 (Sept. 9, 1940), pp. 32, and 35–36.

Oil Well Casing. 2930 Ft. of Welded Casing Run in Kansas Well in Seven Hours, H. F. Simons. Oil & Gas Journal, vol. 39, no. 14 (Aug. 15, 1940), p. 61.

Oxy-Acetylene Cutting. Efficient Torch Cutting, E K. Carlson. Steel, vol. 106, no. 21 (May 20 1940), pp 62–64.

Oxy-Acetylene Cutting. Flame Machining, J. G. Magrath. American Machinist, vol. 84, nos 13 and 14 (June 26 1940), pp. 456–459 and (July 10), pp. 503–506.

Oxy-Acetylene Cutting. Flame-Shaping Brass and Aluminum Oxy-Acetylene Tips, vol. 19, no. 8 (Aug. 1940), pp. 177–179.

Oxy-Acetylene Cutting. Principles and Applications of Practical Machine Flame-Cutting—II, H C. Boardman. Can. Machy., vol. 51, no. 7 (July 1940), pp. 61–62, 64, 66, 69–70 and 72.

Oxy-Acetylene Cutting. Stack Cutting Aircraft Parts. Aircraft Production, vol. 2, no. 8 (Aug. 1940), pp. 253–255.

Oxy-Acetylene Cutting. Oxygen Cutting (Flame Cutting) of Structural Steel. Amer. Soc. Civil Engrs.—Proc., vol. 66, no. 7 (Sept. 1940), p. 1410.

Oxy-Acetylene Cutting Machines. Machine-Cutting with Hand Blowpipe. Oxy-Acetylene Tips, vol. 19, no. 9 (Sept. 1940) pp. 197–200.

Oxy-Acetylene Welding. Oxy-Acetylene Welding of Carbon-Molybdenum Pipe, E. R. Seabloom. Welding Engineer, vol. 25, no. 7 (July 1940), pp. 23–26.

Oxy-Acetylene Welding. Instruction Outline for Welding Steel Sheet and Plate—I, II, III and IV. Oxy-Acetylene Tips, vol. 19, nos. 5, 6, 8 and 9 (May 1940), pp. 101–107, (June), pp. 136–138, (Aug.), pp. 184–186 and (Sept.), pp. 208–211.

Oxy-Gas Welding. Gas Welding of Rolled Aluminum, E. G. West. Metal Industry (Lond.), vol. 56, no. 26 (June 28, 1940), pp. 553–556.

Oxy-Gas Cutting. Cost of Cutting with Butane, Propane and Acetylene—Critical Discussion, E. L. Mathy. Iron Age, vol. 145, no. 20 (May 16, 1940), pp. 43 and 108.

Oxy-Gas Cutting. Economical Oxygen Cutting, H. Lawrence. Steel, vol. 106, no. 24 (June 10, 1940), pp. 62–63.

Oxy-Gas Welding. Technique for Gas Welding of Rolled Aluminum, E. G. West. Inst. Welding—Trans., vol. 3, no. 2 (April 1940), pp. 105–108.

Petroleum Refineries. Welding Requirements of Carbon-Molybdenum Pressure Piping, W. L. Archer. Refiner, vol. 19, no. 7 (July 1940), pp. 232–234.

Pipe Joints. Construction of Cone-Cylinder Joint, W. Seller. Mach. World, vol. 108, no. 2795 (July 26, 1940), pp. 59–60.

Pipe Mills. Bethlehem Installs New Continuous Pipe Mill, L. J. Hess. Iron Age, vol. 145, no. 24 (June 13, 1940), pp. 38–39; see also Steel, vol. 106, no. 26 (June 24, 1940), pp. 47–48 and 78.

Pipe, Steel. Standard Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service. (A 106–39). Am. Soc. Testing Materials—Standard 1939, 8 pp.

Pipe, Wrought Iron. Standard Specifications for Welded Wrought-Iron Pipe (A 72–39). Am. Soc. Testing Materials—Standard, 1939, 4 pp.

Pressure Vessels. Advantages of Low-Alloy Steel for Pressure Vessels, R. Lattice. Welding Engineer, vol. 25, no. 8 (August 1940), pp. 25–29.

Pressure Vessels. Review of Recent Developments in Pressure Vessel Welding, R. Lattice. Welding Engineer, vol. 25, no. 7 (July 1940), pp. 17–20.

Railroad Buildings. Reconstruction of L. N. E. Ry. Coal Depot at Elephant and Castle. Elec. Welding, vol. 9, no. 50 (Feb. 1940), pp. 35–37.

Refrigerators. Application of Resistance Welding to Electric Refrigerator Units, E. R. Spittler. Welding Engineer, vol. 25, nos. 6 and 7 (June 1940), pp. 17–19 and (July), pp. 28–30 and 36.

Welding Rods. Coated Electrodes in Electric Arc Welding, M. S. Layton. Eng. Journal, vol. 23, no. 7 (July 1940), pp. 310–314.

Rolling Mill Practice. Flame Scarfing Billets. J. Heffley. Steel, vol. 107, no. 3 (July 15, 1940), pp. 54–55.

Shafts and Shafting. Shaft-Straightening with Blowpipe. Oxy-Acetylene Tips, vol. 19, no. 9 (Sept. 1940), p. 201.

Sheet Metal. Welding for Enameling, J. C. Lewis. Steel, vol. 106, no. 25 (June 17, 1940), pp. 68, 71 and 79.

Shipbuilding. Cutting in Shipbuilding and Repair—Methods for Production of Main Pieces and Auxiliary Parts, R. E. King. Can. Metals & Met. Industries, vol. 3, no. 5 (May 1940), pp. 124–126.

Shipbuilding. Flame-Cut Ship Plates. Am. Machinist, vol. 84, no. 8 (April 17, 1940), pp. 240–241.

Shipbuilding. Investigation Into Behavior of Welded Rigid Frame Structures, J. F. Baker and J. W. Roderick. Inst. Welding—Trans., vol. 3, no. 2 (April 1940), pp. 83–92.

Shipbuilding. Second Interim Report on Investigation of Welding of Ships' Structures, J. Turnbull, Inst. Welding—Trans., vol. 3, no. 2 (April 1940), pp. 63–82.

Shipbuilding. Shipbuilding on Production Basis, A. J. Grassick. Steel, vol. 107, no. 2 (July 8, 1940), pp. 44–47 and 80; see also Welding Journal, vol. 19, no. 9 (Sept. 1940), pp. 642–646.

Silver. Cold Welding of Silver—II, G. R. Van Duzee and J. M. Thomas. Electrochem. Soc. Trans., vol. 77, 1940, pp. 341–349, (discussion) 349–352.

Soldering. Chemicals for Soldering Fluxes, B. W. Gonser and E. E. Slowter. Can. Chem. & Process Industries, vol. 24, no. 8 (Aug. 1940), p. 394.

Soldering. Fluxes for Soldering, R. W. Gonser and E. E. Slowter. Tin & Its Uses (Pub. by Int. Tin Research & Development Council), no. 6 (July 1940), pp. 1–2.

Sprockets. Knocking out Sprockets. Am. Machinist, vol. 84, no. 12 (June 12, 1940), pp. 414–415.

Steel Hardening. Economy in Machine Replacements. Iron & Steel, vol. 13, no. 11 (July 1940), pp. 413–416.

Steel Hardening. Some Metallurgical Phases of Flame Hardening, R. O. Day. Metals & Alloys, vol. 12, no. 2 (Aug. 1940), pp. 167–171 and, (plate) p. 166.

Steel Testing. Testing Steel with Cutting Flame, J. R. Cady. Am. Soc. Metals—Trans., vol. 28, no. 3 (Sept. 1940), pp. 646–60.

Stresses. Visual Stress Analysis, E. W. P. Smith. Steel, vol. 106, no. 26, June 24, 1940, pp. 60 and 62.

Structural Steel. Welded Construction, F. Hecq. Civ. Eng. (Lond.), vol. 35, no. 409 (July 1940), pp. 209–211.

Testing. Welds and the Testing of Their Endurance, J. H. Hruska. Iron Age, vol. 145, no. 20, (May 16, 1940), pp. 33–37.

Water Pipe Lines. Automatic Welding for Water Mains. Engrg. News-Record, vol. 125, no. 11 (Sept. 12, 1940), pp. 343–344.

Water Pipe Lines. Large Steel Branch Welded to C. I. Pipe of Equal Diameter. Water Works Eng., vol. 93, no. 15 (July 17 1940), p. 936.

Water Wheels. Welding Waterwheels, A. P. Newberry. Elec. West, vol. 85, no. 2 (Aug. 1940), pp. 46–47.

Welders. Measurement of Arc Welding Technique, H. S. Card. Power Plant Eng., vol. 44, no. 6 (June 1940), pp. 66–68.

Welders. Eye Protection Glass for Welding. Elec. World, vol. 114, no. 2 (July 13, 1940), p. 82.

Welding. Minerals Used in Welding, O. C. Ralston and M. W. von Bernewitz. U. S. Bureau Mines—Information Cir. no. 7121 (June 1940), 56 p.

Welding. Proper Sub-Assemblies for Welding, E. W. P. Smith. Iron Age, vol. 146, no. 9 (Aug. 29, 1940), p. 42.

# Statement of the Ownership, Management, Circulation, etc.

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OF THE WELDING JOURNAL, published monthly at Easton, Pa., for October 1, 1940.

State of New York } ss.
County of New York }

Before me, a Notary Public in and for the State and County aforesaid, personally appeared William Spraragen, who, having been duly sworn according to law, deposes and says that he is the Editor of THE WELDING JOURNAL and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are:

Name of — Post Office Address

Publisher, American Welding Society, 33 W. 39th St., New York, N. Y.

Editor, William Spraragen, 33 W. 39th St., New York, N. Y.

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W. SPRARAGEN, Editor.

Sworn to and subscribed before me this 20th day of September, 1940.
(Seal) MARY T. HICKEY
Notary Public, New York County Clerk's No. 134.
New York County Register's No. 0-H-133.
(My commission expires March 30, 1942.)

# Welding Society ACTIVITIES — Related Events

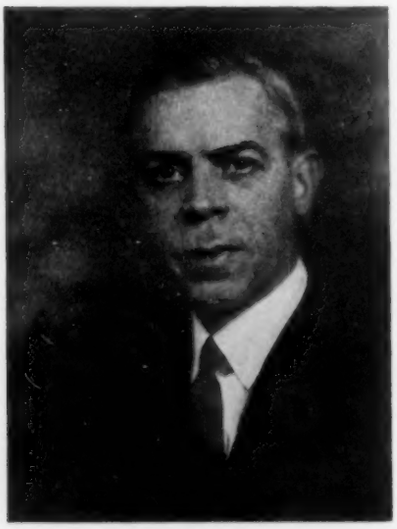
## OBITUARY

### Charles Andrew McCune

Charles Andrew McCune, our beloved Treasurer, died in Atlantic City on Sunday, October 13th. Mr. McCune had been ill for the past few months as a result of a heart attack. Everyone thought that Charlie was recovering and would be his old self again. As a matter of fact, his visit to Atlantic City was in the nature of a rest.

Charlie McCune, as he was known to all of us, was born in Jersey City, October 17, 1879. He received his general education at Cooper Union.

Charlie McCune was Research Engineer and Secretary of the Magnaflux Corporation, 25 West 43rd Street, New York City. Largely as a result of his guiding influence, and far-sighted wisdom, this company, which started from very small beginnings, has flourished to the extent that it has representation all over the world. Charlie



Charles Andrew McCune

McCune is a past-president of the AMERICAN WELDING SOCIETY and of the International Acetylene Association. He was awarded the Samuel Wylie Miller Memorial Medal in 1934 in recognition of his pioneering in the development and application of fusion welding.

From the position of Chief Draftsman of the Safety Car Heating and Lighting Company, in 1904 he became Assistant Engineer, and later Chief Engineer, of the Commercial Acetylene Company, retaining this position until 1916 when he became Sales Engineer of the Page Steel and Wire Company. In 1924 Mr. McCune was appointed Director of Research of the American Chain Company and, after holding this position for six years, he resigned in 1930 to become Director of Research of the Welding Engineering and Research Corporation. Following the dissolution of this corporation, he assumed the position as Director and Secretary of the Magnaflux Corporation.

Mr. McCune was one of the pioneers of welding. In 1905 he cooperated in successfully developing the type of cylinders used today for the safe storing and transportation of acetylene, and in devising other safety devices. With the Page Steel and Wire Company he actively continued his early investigations in the field of welding rods and electrodes for both gas and arc welding. As a member of the Emergency Fleet Welding Committee he was chiefly responsible for the crystallizing of specifications for these products. Mr. McCune was one of the founders of the AMERICAN WELDING SOCIETY. He has been Treasurer since 1923. He also served as a member of previous Boards of Trustees for the award of the Samuel Wylie Miller Memorial Medal.

He was a member of The American Society of Mechanical Engineers, the American Society for Testing Materials and the Advisory Board of the United States Bureau of Standards.

Mr. McCune was author of numerous papers on acetylene and its uses, the metallurgy, of welding rods and welds, the manufacture of iron and steel wire and research methods in iron and steel production. He collaborated with other authors in the preparation of articles on gases, metallurgy, and welding. He cooperated in successfully developing practical means for locating defects in metals by magnetic methods of testing.

The AMERICAN WELDING SOCIETY owes much to Charlie McCune for his steadfast promotion of modern welding processes as well as for his able handling of its financial affairs.

Space will not permit to give a detailed account of all of Charlie's services and connections with the AMERICAN WELDING SOCIETY. His work as Chairman of the Filler Metal Specifications Committee for a long period of years, however, deserves special mention.

Charlie was always considered a member of the inner family of the AMERICAN WELDING SOCIETY. He gave freely of his time, council, and advice. He was Chairman of the Convention Committee, and largely through his efforts the welding section of the National Metals Exposition has attained its present degree of success.

Charlie was full of the milk of human kindness. He went out of his way at all times to drop oil on troubled waters, and in promoting harmony and cooperation. The AMERICAN WELDING SOCIETY has lost one of its dearest friends.

Surviving are his wife, Mrs. Della J. Varley McCune; his mother, Mrs. Mary T. Carroll McCune; a son, Donald McCune; three daughters, Mrs. Charles Lewis, Mrs. Joseph Gannon, and Mrs. Alexander Tutles; a brother, Fred McCune; a sister, Mrs. Abner McLaud, and six grandchildren.

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## RESOLUTION CONCERNING CHARLES A. McCUNE

The following Resolution was unanimously adopted at the Business Meeting of the AMERICAN WELDING SOCIETY in Cleveland, October 25, 1940.

WHEREAS, the AMERICAN WELDING SOCIETY has suffered one of the greatest losses in its history through the death of Mr. Charles A. McCune, Treasurer of the Society and Chairman of its Convention Committee, and

WHEREAS, all of us have lost in the death of Charlie, one of our dearest and most loyal friends,

*Resolved*, that the members of the A. W. S. assembled at its 21st Annual Business Session in Cleveland, Ohio, pay tribute to the memory of our beloved past-president, chairman of Convention Committee, Treasurer, also one of the founders of the Society, who has been largely responsible for the success of our Annual Meetings and Conventions, including this one, and the Secretary on behalf of the Society be requested to send an appropriate letter of sympathy to Mrs. McCune and to assure her that the example of faithful, unselfish and cooperative service which he set, will live on as a permanent memorial to a rare soul, her husband, and our beloved friend and co-worker.

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## A MESSAGE FROM OUR PRESIDENT

### A Statement of Policy

The sound financial policy of the Society's management has resulted in not only a balanced budget but a small reserve. The technical policy has given the Society an increasing prestige and an increasing usefulness. THE WELDING JOUR-

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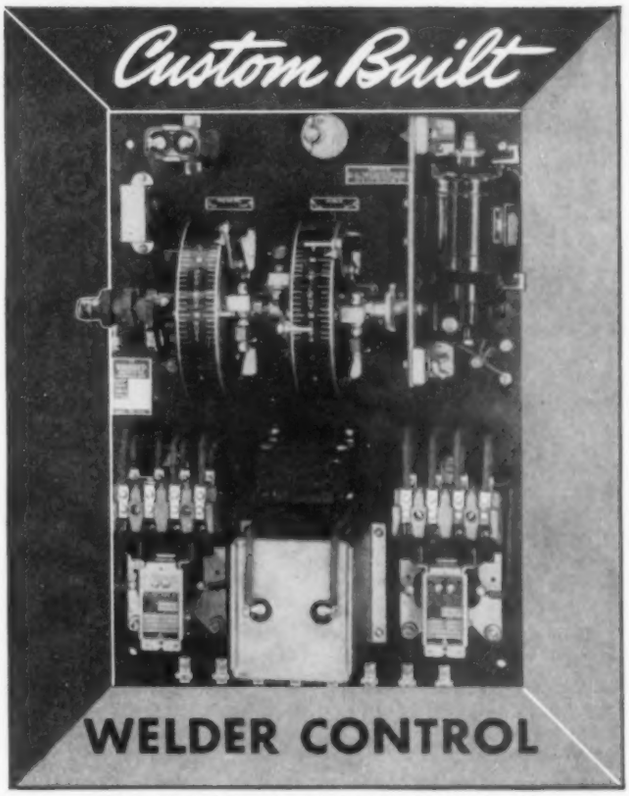


*This custom built timer is used with a Syncro-Break welder contactor to make practical operating speeds as high as 325 welds per minute.*

In this day of specialized machinery for single purpose and high speed production, automatic resistance welder control is called upon to perform new and increasingly difficult cycles of operation. Square D welding engineers have both the experience and equipment to provide a solution to new problems encountered.

***A CASE STUDY*** – – One automobile manufacturer required:

A Production rates as high as 325 welds per minute.

B An accurate weld time of less than 3 cycles because of the high speed operation involved.

C Even spot spacing and regular cadence in operation to avoid tiring the operator.

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E Reliable performance over the millions of operations that would be expected in a single production program.

***THE SOLUTION BY SQUARE D*** – – A revolutionary type of timer construction was developed, including:

A Compensation for operating speed limitations of the pneumatic welding tool. (A Delay time was added to the usual Squeeze, Weld, Hold and Off periods, to provide adequate pressure on the first weld of a series without reduction in operating speed.)

B A synchronous motor driven timer mechanism for accuracy.

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E Ball bearings, precision construction of motor driven parts and high speed control relays that operate *only* to begin and end a series of spot welds—not each weld. A ***Syncro-Break*** contactor was used to break the power circuit without arcing at its contacts, giving maximum service with minimum maintenance.

*An Invitation:* Square D engineers are always ready to give individual attention to your problems. If they cannot be solved using one of the many standard control devices available, consideration will be given to such modifications or new developments as may be necessary.

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NAL has an excellent reputation and is a leader in its field.

*National Defense.*—During periods in which National Defense is paramount, there are dislocations and disturbances in normal industrial life due to the requirement of providing additional production facilities and training additional labor. Time is the essence of these demands. There is need of cooperative effort, of pooling of technical resources and knowledge so that production may be stepped up with the least economic waste.

The enlargement of existing plants and the construction and equipment of new plants are taking place in the welding industry. There is a need for an increased number of engineers and skilled workmen for these new facilities. This expansion involves training.

During normal peace-time activities, the production of munitions is so small that industry has little opportunity to gain a knowledge of how munitions function and what requirements must be met in their production. With normally small peace-time appropriations, government agencies are unable to build up technical organizations comparable to those of industrial corporations. There is bound to be a lack of information regarding military products—information essential to establishing method of production and quality control. If delays in production of munitions are to be kept to a minimum and if waste due to improper quality control is to be avoided, there must be close technical cooperation among all concerned.

The current program of the AMERICAN WELDING SOCIETY should be concerned primarily with stimulating training and in fostering increased technical cooperation.

The programs of local sections and of the National Society should consider the needs of this new industry—National Defense. The platform of the Society should be held open to discussions of technical problems arising from production for National Defense and to a fuller understanding of the military products.

The AMERICAN WELDING SOCIETY is, and will be, available to help solve the problems of National Defense. The Society invites all associated with National Defense within the scope of its activities to participate in its work and make use of its organization and experience. The Society can be of maximum service to National Defense only provided those concerned directly with National Defense make use of the Society by direct intimate participation in it.

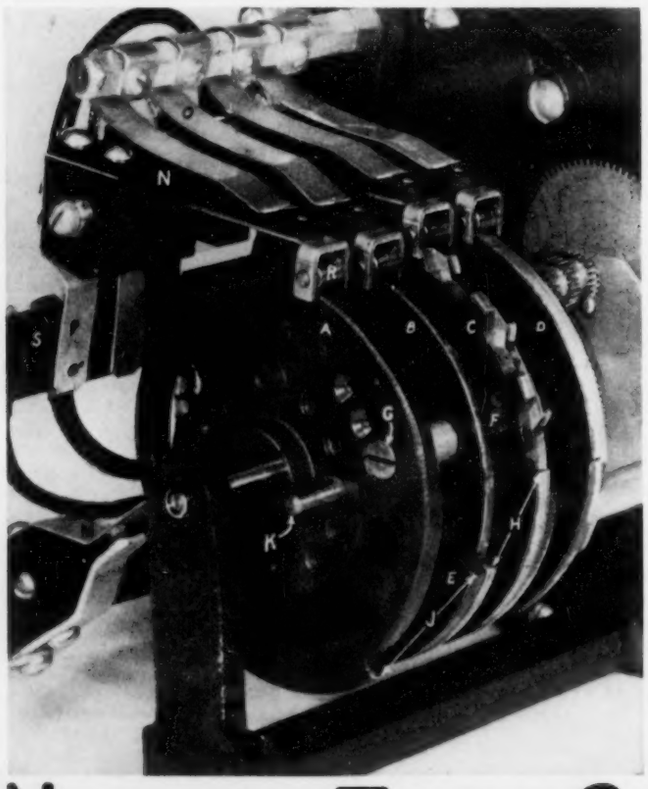
*Sections.*—The continuous growth of the Society during the past few years is closely associated with the activities of the Sections. There is a lack of up-to-date welding literature but a high rate of progress in the art and science of welding. The conditions are conducive to the organization of strong decentralized technical programs. This is probably the most important work of the Society and essential to the most rapid development of National Defense.

*Districts.*—Our organization provides for District officers and contemplates District meetings. It is hoped that district or regional meetings with technical sessions will be organized.

Our District Vice-Presidents will be requested to study the activities of local sections of their jurisdiction and to arrange, if practicable, for a meeting of delegates, preferably chairmen of their local sections. They should consider problems of local organization and also problems of the relation of the national organization to local sections and other matters of promoting the general interest of our Society. Those reports and recommendations affecting the general policy and in the organization of the Society, if not acted upon by the Executive Committee, will be added to the agenda of the District and Section meeting for the more thorough discussion and recommendation of all Districts and Sections.

Study will be given to the improvement of our Section-District-National Headquarters organization.

*Technical Committees.*—The Society can be of increased service to industry and to National Defense by accelerating the programs of its technical committees. There is always a delay in bringing the Society's codes and Standards into conformity with satisfactory industrial practice, but work should be organized to reduce these delays to a minimum. As industry develops new practices and processes, or new products, the organization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NATIONAL INTERRUPTED WELD TIMERS

and Eliminated Flash Marks and Indentations.

HERE, is a New Achievement from Research,

NATIONAL INTERRUPTERS,

Unexcelled for Heavy Metal Welding, now Make Cleaner Welds on Body Sheets, Save almost 50% on Points, and Reduce Current Cost by Halving TRANSFORMER KVA Capacity.

At the left, is the rotating cam section of the Interrupter.

Cam A roller drops and closes the pressure valve, with J, the squeeze period.

Cam B drops and initiates the weld. H the first "On Weld" time, longer for pre-heating, and followed by a series of rapid "Off and On" pulsations that pump the heat through the metal to be welded. The low portions in Cam C, are adjustable "off" intervals.

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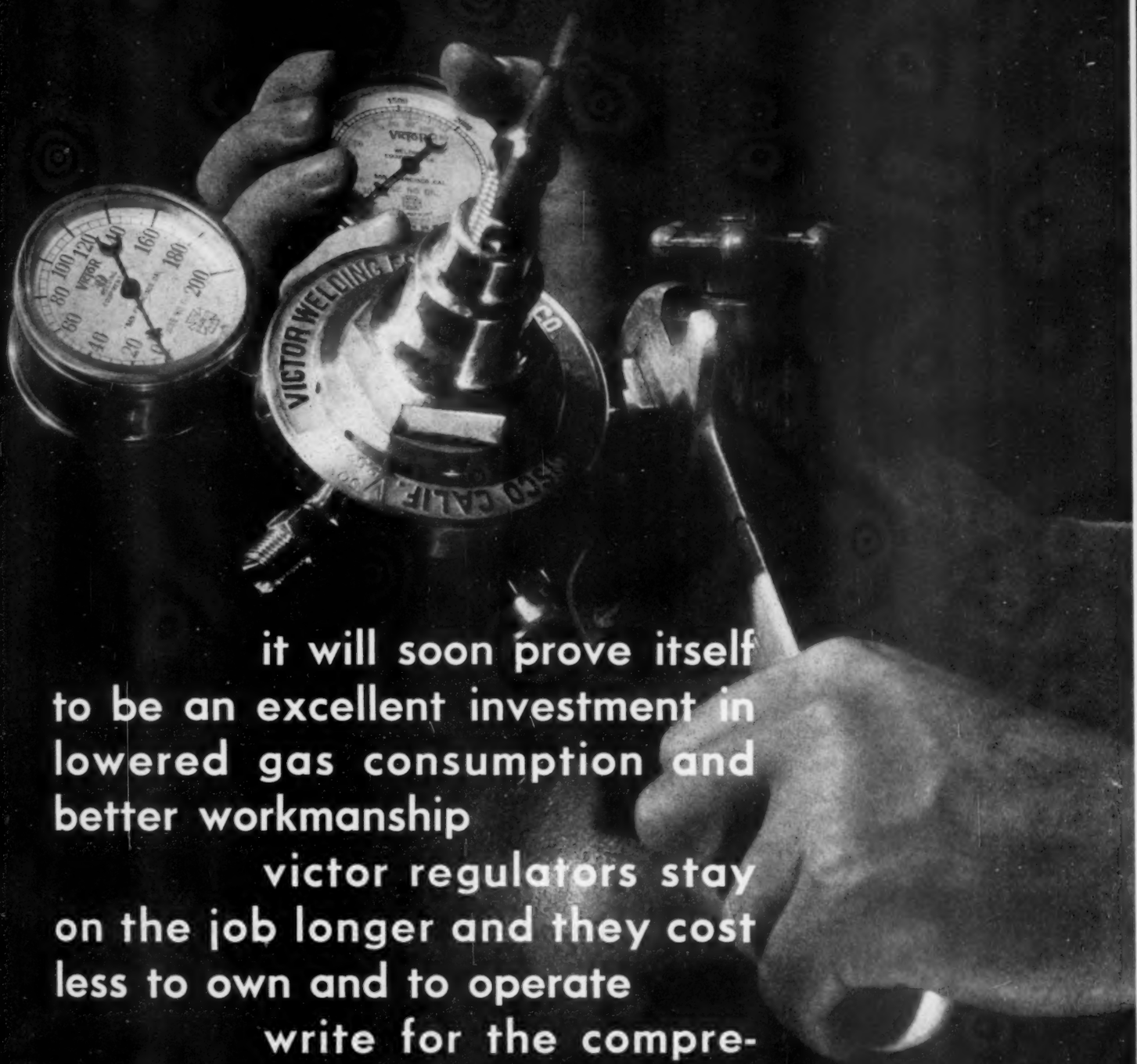


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of the Society should be available to develop Standards and codes for the protection of both producer and consumer.

In standardization and codification work, the technical society is the mechanism by which industry can accomplish its ends to the satisfaction of both producer and consumer and within the public interest.

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## ANNUAL MEETING OUTSTANDING SUCCESS

The Twenty-First Annual Meeting of the Society held in Cleveland during the week of October 20th went down in history as the greatest meeting the Society has ever held. A total registration of 1882 surpassed all previous records by a wide margin. Fifty-two papers were presented, the greater portion of which were published in the October JOURNAL or made available in preprint form. The attendance at the Annual Banquet and Dinner numbered more than 425, representing maximum seating capacity.

The meeting was formally launched with the President's Reception on Sunday afternoon attended by several hundred members of the Society. Refreshments were served. The meetings opened promptly at 9:30 on Monday morning with the presentation of medals and awards. A description of these awards is given elsewhere.

All of the technical sessions were well attended and the discussion at times was quite brisk.

Smooth operation of the technical sessions was assured by authors' breakfast meetings at which the authors and presiding officers, as well as supervisors, got together for "dress rehearsals" and the ironing out of important details.

A most intersting meeting was held of Section delegates at which Mr. K. L. Hansen, Senior Vice-President of the Society, presided. A number of items were discussed and actions taken which will be reported in a later issue of the JOURNAL.

Comparable with the huge success of the technical sessions, the National Metal Exposition surpassed all records both as to attendance and the size and number of exhibits.

The newly elected officers were installed at the business session held late Friday morning, after the presentation of the President's Report. This report is published elsewhere in the JOURNAL.

The memory of Charles McCune was honored on four different occasions. At the opening of the convention on Monday, the entire membership was asked to stand and bow their heads in silence for a minute. At the Annual Banquet, Dr. Adams paid tribute to the untiring energy and devotion of Charles McCune, his loyalty and friendship to everyone connected with the Society; this was followed by a testimony of appreciation of Mr. McCune by his associate Dr. A. V. De Forest. At the business session, Mr. Meadowcroft proposed a resolution, given elsewhere, which was formally adopted. At the Board of Directors' meeting later in the day, a committee was appointed to prepare appropriate formal resolutions.

At the business meeting a special vote of thanks was extended to Mr. F. L. Plummer and the numerous committees of the Cleveland Section that assured the outstanding success of the 21st Annual Meeting. Similar thanks were given to the national committees concerned.

This year unusually interesting and entertaining events were provided for the ladies and special thanks are due to the committee on ladies' entertainment.

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# EMPLOYMENT SERVICE BULLETIN

## SERVICES AVAILABLE

A-383. Electric and Acetylene Welder. Experience slight but rapid, accurate, willing worker. Salary secondary. Married. Can furnish excellent references from former employers in mechanical field. Heavy gage metal preferred.

A-384. Young man, age 24, citizen U. S., high-school education, desires position as apprentice welder. Over six months' experience on oil tanks.

## R. W. M. A. ANNOUNCES PRIZE AWARDS

On Monday, October 21st, at the opening session of the AMERICAN WELDING SOCIETY's 21st Annual Meeting in Cleveland, Ohio, E. C. Smith, President of the Resistance Welder Manufacturers Association announced the winners of that association's Prize Essay Contest and awarded the prizes.

The winning articles and their authors, together with the prizes won, follow:

First Prize—"Electro-Magnetic Stirring Action in a Spot Weld," by A. M. Unger, H. A. Matis, W. A. Knocke, Pullman Standard Car Manufacturing Co..... $300

Second Prize—"Fundamentals of Resistance Welding," by R. S. Pelton, starting page 426-s, Supplement, October 1940..... $200

Third Prize—"Resistance Flash Welding of Strip in Steel Mills," by J. H. Cooper, starting page 721, October 1940 issue..... $100

Four Fourth Prizes—$25 each—"Applications for Pulsation Welding Broaden the Field of Resistance Welding," Part III by H. C. Cogan and R. S. Pelton, starting on page 568, August issue.

(*Note:* The R. W. M. A. believe this paper should be considered with Parts I and II by the same authors, published in the February and April issues.)

"Spot Welding in Aircraft Construction," by C. F. Marschner, starting page 750, October 1940 issue.

"Electro-Brazing Methods," by R. J. Wensley, starting page 754, October issue.

"Measurement of Contact Resistance," by W. B. Kouwenhoven and J. Tampico, starting page 408-s, Supplement, October 1940.

Judging this contest, sponsored by the R. W. M. A., were Dr. Wendell F. Hess, R. P. I., Chairman of the Judges, with L. W. Clark of Detroit Edison Company and Dr. Comfort A. Adams of Edw. G. Budd Manufacturing Co., assisting.

# Page-Allegheny Stainless Steel Electrodes

## BETTER WELDS—LOWER WELDING COSTS FOR ALL STAINLESS STEEL WELDING

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*Milk tanks made of 18-8 Stainless, welded with Page-Allegheny 25-12 Electrodes to insure high resistance to corrosion without the need for stabilization.*

There is one electrode that is suited best to whatever of the many combinations of stainless steel you want to weld. • And you can bank on finding that one best electrode in the Page-Allegheny group—developed by Page in conjunction with the largest tonnage producer of Stainless Steel. • All of these Page-Allegheny Electrodes are suitable for flat, vertical or overhead welding. • All have a uniform, heavy flux coating. • When the recommended electrode is used, the weld metal in welds has the same physical and chemical properties as the metal being welded. • You will find it worth while to get welding electrode recommendations from your local Page Distributor. You get better welds at lower welding cost.

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**Winners of Prizes Given by the Resistance Welder Manufacturer's Association. Reading Left to Right with Geo. T. Horton, Society President Looking On (at Extreme Left) They Are: Joseph Tampico, J. N. Cooper, A. M. Unger, C. A. Matis, W. E. Knocke, R. S. Pelton and E. C. Smith Presenting the Prizes**

The R. W. M. A. will continue these contests, which will be annual affairs. All papers submitted from now on to the AMERICAN WELDING SOCIETY on Resistance Welding will be eligible to participate in the Prize Contest whether they are submitted to the Contest Editor or not, providing they are published in the A. W. S. JOURNAL. However, all papers submitted to the Contest Editor will automatically become eligible, whether they are published in the A. W. S. JOURNAL or not. The 1940–41 contest, with the same awards indicated above, will end September 1, 1941, on which date the next annual R. W. M. A. Prize Contest will begin.

Rules governing the R. W. M. A. contest were published in the May 1940 issue of THE WELDING JOURNAL and will be repeated in the Year Book published as the December issue of the Journal.

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## WELDING SOCIETY AWARDS MILLER AND LINCOLN MEDALS AT OPENING SESSION OF ANNUAL MEETING

Presentation of the 1939 Miller Memorial Award and the Lincoln Gold Medal for 1939–40 featured the opening session of the AMERICAN WELDING SOCIETY's annual meeting at Hotel Cleveland.

The Samuel Wylie Miller Memorial Medal was awarded to Mr. William Spraragen, technical secretary of the AMERICAN WELDING SOCIETY and editor of THE WELDING JOURNAL. Award of the Lincoln Gold Medal, donated to the AMERICAN WELDING SOCIETY by Mr. James F. Lincoln, president of The Lincoln Electric Company, Cleveland, Ohio, was made to Messrs. H. J. French and T. N. Armstrong, Jr. of the International Nickel Co., Inc., New York City.

The award of the Miller Medal was made for conspicuous contributions to the art and science of welding during 21 years in the field, also for the quality and intensity of the service which has been marked throughout by unusual energy, loyalty and integrity.

The Lincoln Award, which is presented each year for the paper which contributes most to the year's development of welding, was made for "Weld Hardening of Carbon and of Alloy Steel," published in the October 1939 issue of THE WELDING JOURNAL and presented at the annual meeting in Chicago, Oct. 23–27, 1939.

**Presentation of the Samuel Wylie Miller Memorial Medal to Mr. William Spraragen, Technical Secretary of the American Welding Society and Editor of The Welding Journal**

**Messrs. French and Armstrong of the International Nickel Co., Inc., Receiving Lincoln Gold Medal**

**H. J. French**

The paper occupies 9 pages in the JOURNAL, contains 19 charts and covers test methods, carbon steels, ternary alloy steels, welding speed and plate thicknesses, precooling, maximum hardness obtainable, preheating steel with high hardening capacity, comparisons of complex alloy and carbon steels.

**T. N. Armstrong, Jr.**

Messrs. French and Armstrong, Lincoln Medal recipients, are both metallurgists with the International Nickel Company.

Mr. French, graduate of the School of Mines, Columbia University (degree of Metallurgical Engineer), first worked for the American Smelting & Refining Co. in Utah, following which he became metallurgist for the General Vehicle Co. on Long Island;* member Signal Corps, U. S. Army during the World War; assistant physicist, physicist, metallurgist, senior metallurgist and finally assistant chief, Division of Metallurgy, Bureau of Standards, from 1919 through 1929; in 1929 became member metallurgical staff research laboratories of International Nickel Co. at Bayonne, N. J.; and in 1931 was transferred to New York in charge of alloy steel and iron developments; received the Henry Marion Howe Medal of the American Society for Steel Treating in 1931 and was the Edward deMille Campbell Memorial Lecturer for the American Society for Metals in 1933; member of the American Society for Metals, American Society for Testing Materials, associate member of the American Iron and Steel Institute, the American Institute of Mining and Metallurgical Engineers and at present is a member of the Board of Trustees of the American Society for Metals and a member of the executive committee of the Iron and Steel Division of the American Institute of Mining and Metallurgical Engineers.

Mr. Armstrong received his engineering training at the University of Kentucky. After leaving school, spent two years as an open-hearth furnace helper at Andrews Steel Co., Newport, Ky. Then followed 7 years service as metallurgist at the Norfolk Navy Yard, Portsmouth, Va. Joined the staff of the Development and Research Division of the International Nickel Co. in 1935 working on steel development.

# A "Wheel of Progress" Keeps Moving

## THANKS TO TOBIN BRONZE!

### This 2½ ton gear, although broken in several places, was back on the job only six days after it failed

This gear looked something like Humpty-Dumpty... it was so severely broken that it looked almost impossible to repair. But, here, as in many other emergencies, Tobin Bronze repair welding performed the "impossible," in the shortest possible time.

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Tobin Bronze rods are stocked by leading jobbers throughout the country. When ordering, make sure you get genuine Tobin Bronze. Each rod is trademarked for permanent identification.

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*The Hebeler Welding Co., Buffalo, N. Y., repair-welded this 2½ ton gear in 64 man hours with 250 lbs. of Tobin Bronze.* 40123

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## AWARD OF THE SAMUEL WYLIE MILLER MEMORIAL MEDAL FOR 1939

### Presentation Address by Dr. D. S. Jacobus

This medal is awarded in memory of our dear old friend and co-worker, Sam Miller, or "sound weld" Miller, as he was appropriately called. He was a fine man, a loyal friend and one of the foremost pioneers in the development of fusion welding. We are honoring his memory at the same time that we do honor to the medalist.

This medal is awarded for conspicuous contributions to the art and science of welding. Although some of these contributions are much more spectacular than others, it often happens that the least spectacular are of the greatest value.

This is the case with the 1939 medalist, Mr. William Spraragen. A mere recital of his activities and connections seems pale and cold when compared with the value of the service rendered. But as such a recital is customary, here are the high points.

Born in Warwick, New York, on May 20, 1895.

Graduated from Union College with a B.E. degree in 1916.

One year testing engineer for the Westinghouse Electric and Manufacturing Company and a Wire Company.

Two years as instructor in Electrical Engineering in two state universities.

War Service—Ballistic Engineer of the War Department and later research assistant, devoting his whole time to the planning and conducting of the Welding Research program for the welding committee of the Emergency Fleet Corporation.

For fifteen years Executive Secretary of the Division of Engineering of National Research Council and of the American Bureau of Welding.

For eighteen years editor of THE WELDING JOURNAL which is acknowledged to be the world's leading welding magazine.

For fifteen years Technical Secretary of the AMERICAN WELDING SOCIETY and for the past five years Executive Secretary of the Engineering Foundation Welding Research Committee.

W. Spraragen

On the side he is co-author of an excellent Handbook of Engineering Mathematics, of articles on Welding and Research and sections on welding in the *Mechanical Engineer's Handbook* and in the *Encyclopaedia Britannica*. He has been editor of the *Welding Handbook* from the beginning, joint editor of "Profitable Practice in Industrial Research" and co-author of forty-five Critical Digests of Welding Literature on specific subjects.

The striking point of this record is that he has devoted a very large part of his professional career, namely, twenty-one years, to the Welding Society and to Welding Research. But the more striking point is not the record as given but the quality and intensity of the service which has been marked throughout by unusual energy, loyalty and integrity.

Only a few of the society pioneers of this society who have stood by through the period of its development, who have participated in the struggles involved in maintaining the ideals set up at the beginning and in bringing it to its present high rank as an engineering society can appreciate the important part played by our medalist throughout this period. At times it has meant a courageous stand for principles and a willingness to fight for it. I know of no better fighter than Bill Spraragen.

I am sure that you will join me in the conviction that we are not only giving him a well-deserved recognition, but that we are at the same time honoring the Society and the memory of Sam Miller.

It is, thus, with great pleasure that I present Mr. William Spraragen for the 1939 award of the *Samuel Wylie Miller Memorial Medal.*

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## ACCEPTANCE OF SAMUEL WYLIE MILLER MEMORIAL MEDAL

### By W. Spraragen

On this occasion it is fitting that we recall the memory of Sam Miller. I am reminded of one particular battle in those days in which we successfully followed Sam's leadership in persuading mechanical engineers that the butt joint was superior to the double lap joint in the construction of pressure vessels. The engineers were used to the lap joint, and to change over to the butt joint would, in their opinion, bring about insurmountable obstacles. It was an interesting battle, with the outcome of which you are entirely familiar. Today we have the same battle with civil engineers in the acceptance of the butt joint for building and bridge construction. Again, through researches now planned, I am sure we will be successful and we will be able to design for welding in structural work and not merely substitute welding in designs intended essentially for riveting.

It is a bit unusual for a paid employee to receive a medal and in accepting this honor I feel that it is a symbol representing the work of most of you gentlemen in the audience and literally hundreds of other hard-working members who unfortunately could not be present. It would not be possible for me to name all of you. I know you will forgive me, however, if I take this opportunity to acknowledge publicly my indebtedness first to my guiding star, Dr. C. A. Adams; secondly,


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**The Trade-Name is "ANTI-BORAX"**

*Ask for Them* *Unequalled for Quality*

**A Flux for every metal: Cast Iron Welding Flux No. 1.; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; "Anti-Borax" Tinning Compound No. 11.**

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to our dear departed friend, Charlie McCune; and thirdly to my associate, Miss M. M. Kelly, National Secretary of the Society.

This would have been one of the happiest moments of my life if Charlie could have kept his promise to be present. I feel particularly proud in having the Medal presented by Dr. D. S. Jacobus, one of America's outstanding engineers.

### PLANT INSPECTION TRIP

The final activity of the Society's Twenty-First Annual Meeting was an inspection trip through the plant of the Midland Steel Products Company in Cleveland. Approximately fifty members and guests participated in the visit and were privileged to watch the fabrication of automobile chassis frames, differential housings and other parts. The visitors were shown each step of the fabricating operations, starting with the unfabricated steel sheet or plate and ending with the finished and painted units.

The group was subdivided into small groups of eight or nine, and conducted through the plant by individual guides who explained the various operations and answered the many questions that were asked. The operations in actual progress included shearing, punching, pressing, hot forging, heat treating and practically every form of welding. Much interest was shown in some of the applications of automatic metal arc welding, and in the extensive use of resistance welding processes, including flash butt welding, spot welding and projection welding.

The operation in which the group seemed to find the greatest interest was the automatic welding of tubing by the atomic hydrogen process. The high quality of the welds obtained in this operation was demonstrated very effectively by the severe forming operations to which the tubing was later subjected.

### A. S. M. E. ANNUAL MEETING

Keynoting better living and greater industrial progress through engineering, the Sixty-First Annual Meeting of The American Society of Mechanical Engineers to be held in New York City, Dec. 2–6, 1940, with meeting headquarters at the Hotel Astor instead of the Engineering Societies Building, is expected to attract to it about 5000 engineers and executives from the United States and Canada. More than 100 technical papers on such specialized mechanical engineering subjects as aeronautics, applied mechanics, fuels, hydraulics, metals engineering, machine-shop practice, management, materials handling, petroleum, steam power, railroads, textiles, heat transfer, and process industries, will be presented by leading experts in the field. To accommodate all these papers, 44 simultaneous sessions are being scheduled, including six on Monday evening, Dec. 2nd.

### IMPORTANT TIE-UP

An arrangement has been entered into between the National Cylinder Gas Company and The Bastian-Blessing Company which becomes effective at once. National will use the facilities of The Bastian-Blessing Company and engage in the production of a complete line of gas welding and cutting equipment under the Rego trade mark. The arrangement perpetuates the activities of the fine Rego distributor organization, making Rego available not only through such distributors but also through National district sales offices in all principal cities, according to Ellsworth L. Mills, Vice President of The Bastian-Blessing Company of Chicago.

### TRANSLATION

A dozen copies of a translation of a German welding article have been made available by the Babcock & Wilcox Company. The article is entitled "On the Welding of Tubes of Chromium-Molybdenum Steel," was written by P. Wimmer, and was published in *Autogene Metallbearbeitung*, **32**, No. 24, pp. 345–352, Dec. 15, 1939. The article describes the strength, hardness and microstructure of oxyacetylene welds made with two filler rods in Cr-Mo steel tubes 1 inch diameter, $^1/_{16}$ inch thick containing 0.3 C, 1.0 Cr, 0.2 Mo. A copy of the translation may be secured from the Welding Research Committee.


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Show up in --- the show down

Here's a factual record told in pictures that can't be ignored by anyone who wants reduced welding costs.

The test tips marked set No. 1 are both made of Mallory 22 Metal. After 5050 welds each, the slight point deformation shows them to be good for at least another 5,000 or 10,000 welds before redressing.

Test tips marked set No. 2. Specimen "A"—Mallory 22 Metal. Specimen "B" made of a competitive material. Redressing needed for Specimen "B" after only 1850 welds.

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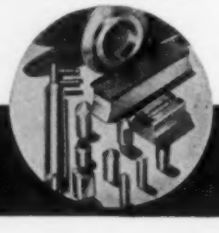

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ROD COATING MATERIALS

Crude "milling" operation at a small Cuban mine. The screen is raised and lowered into the pool, obtaining thus a "jigging" action. Most of the "tailing" is picked off by hand. The pole serves to raise and lower the screen.

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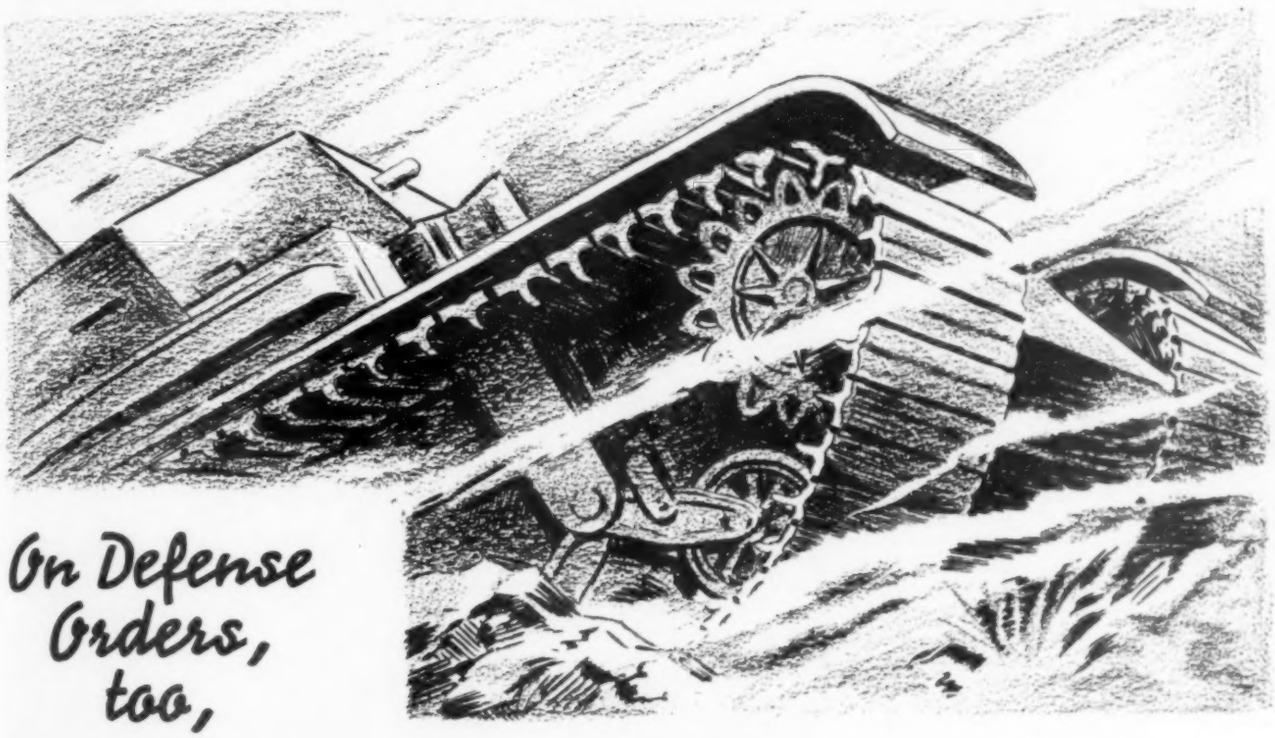
PHILADELPHIA, PA.

# FIFTEEN YEARS PROGRESS BY RESISTANCE WELDING



*On Defense Orders, too,*

# INVESTIGATE THESE JOBS *for* RESISTANCE WELDING

● Often Resistance Welding has made possible improved production methods and substantial cost savings by joining two or more comparatively simple stampings to replace an intricate or difficult one. Similarly, it can join two or more simple forgings. Then, too, it can join forgings to stampings, or one metal to a dissimilar one. These are but a few of many developments that are essential to present day conditions—speed, labor savings, and modern engineering. They have been proven in the automotive, aircraft, electrical appliance and other industries by speeding production and cutting costs materially.

Consult any of the member companies listed here. They have experienced engineers available who can show you what results Resistance Welding can accomplish in your plant.

# RESISTANCE WELDER MANUFACTURER'S ASSOCIATION

505 Arch Street Philadelphia, Pa.

RESISTANCE WELDER MANUFACTURERS ASSOCIATION • RWMA

## MEMBER COMPANIES

Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.
Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.
Welding Machines Mfg. Co., Detroit, Mich.
Acme Electric Welder Company, Los Angeles, Cal.
American Electric Fusion Corporation, Chicago, Ill.
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Co., Detroit, Mich.

## ASSOCIATE MEMBER COMPANIES

P. R. Mallory and Co., Indianapolis, Ind.
S-M-S Corporation, Detroit, Mich.
Electroloy, Inc., New York City
Welding Sales and Engineering Co., Detroit, Mich.

## CONFERENCE SET TO HIGHLIGHT NATIONAL CHEMICAL EXPOSITION

New discoveries and developments in the service of chemistry and its application and progress in many fields of activity will be discussed by foremost authorities in America at an Industrial Chemical Conference, which will be a feature of the National Chemical Exposition to be held December 11th through 15th at the Stevens Hotel in Chicago.

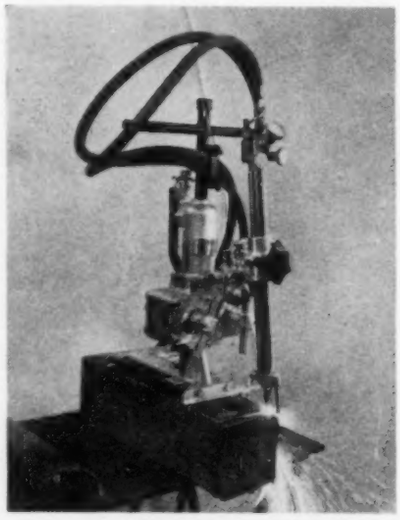
Announcement is made that the directors of the exposition, sponsored by the Chicago Section of the American Chemical Society believe that its objectives may be enhanced by furnishing the latest scientific information as well as practical education that will result from a visit to the exhibition.

"We have arranged for this Industrial Chemical Conference an excellent program of papers in the nature of symposia on 'Newer Developments in Chemistry and Chemical Engineering,'" said Dr. R. C. Newton, chairman of the show committee. "The program is timed to afford those who wish to hear the talks in which they are interested ample opportunity also to view the show."

Technical sessions for this conference have been arranged for Thursday afternoon and evening, December 12th, Friday forenoon, December 13th, and Saturday afternoon, December 14th. The regular monthly meeting of the Chicago Section of the American Chemical Society will be held on Friday evening, December 13th.

## BAR-CUTTING MACHINE

A new oxyacetylene bar-cutting machine designed for a number of steel mill cut-off operations has just been announced by The Linde Air Products Company, a Unit of Union Carbide and Carbon Corporation. This portable machine, known as the Oxweld CM-35 Bar-Cutting Machine, will cut rounds or squares with a minimum of adjustment and is driven by a self-contained spring-power unit, the speed of which is hydraulically controlled.



Bar Cutting Machine in Operation

Heretofore heavy and complicated attachments have been used on straight-line cutting machines to obtain the desired blowpipe motion when cutting rounds, in which the blowpipe must move in a vertical arc, or when cutting squares with a swinging blowpipe. The CM-35, however, is simple in operation, the correct motion for cutting either rounds or squares being transmitted positively to the blowpipe by an easily adjusted linkage mechanism. Hydraulic control provides an ideally smooth blowpipe travel with an almost infinite variation of cutting speeds between 1 and 75 in. per min.

## ELECTRODE SELECTOR CHART

To simplify the selection of the proper electrode for the job at hand, Air Reduction has announced the publication of an Electrode Selector Chart for use by arc-welding operators.

Under separate guides, listed according to the metal to be welded, the chart enumerates such things as the suggested type of electrode, welding procedure and recommended voltage and current values.

Attractively designed, the Electrode Selector Chart is bound so that it can be hung either on the welding machine itself or on an adjacent wall within easy reach of the operator. Copies may be obtained by writing to Air Reduction Sales Co., 60 East 42nd Street, New York, N. Y.


National

Carbide

DEPENDABLE

EFFICIENT

ECONOMICAL

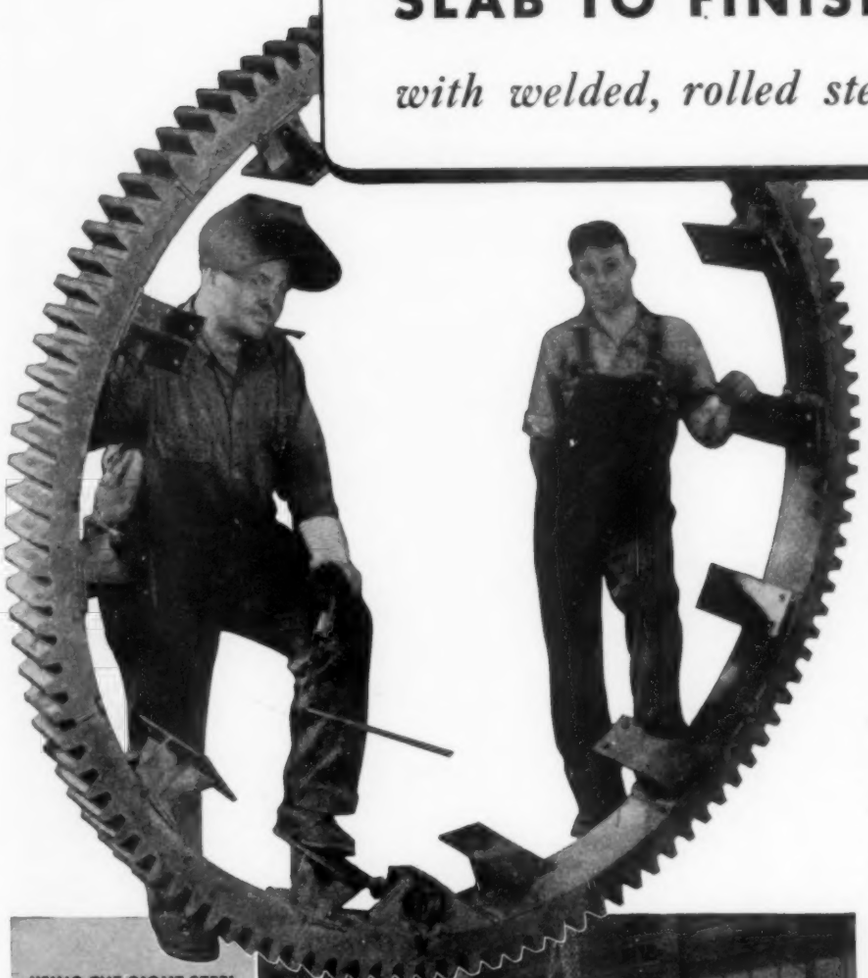
FOR WELDING and CUTTING

Use National Carbide in the Red Drum

Lincoln Building — NATIONAL CARBIDE CORPORATION — New York, N. Y.

# 18 HOURS FROM SLAB TO FINISHED GEAR

*with welded, rolled steel construction*



THIS large gear with a pitch diameter of seven feet five inches and a six-inch face, for use on a six-foot rotary kiln, was fabricated by the Manufacturers' Steel Supply Co. in record time by welding rolled steels. It could not have been produced by any other method as quickly or cheaply.

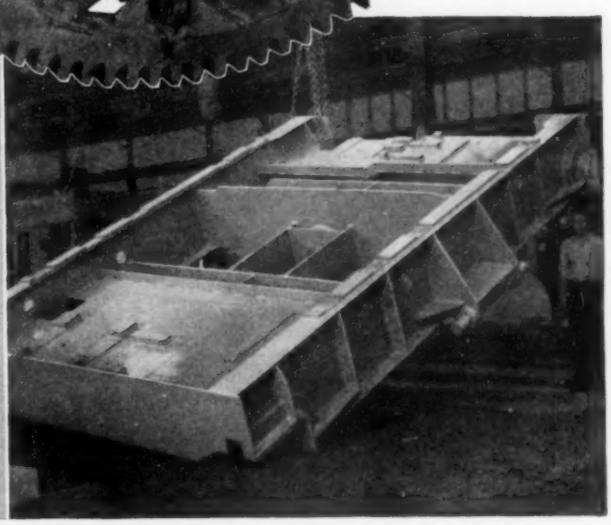
However, greater by far than the advantage in time saving, is the new freedom welded construction has given to the industrial designer. Limited only by functional requirements, he can suit his steels to each particular part, effect any combinations and include castings where expedient. The result: greater efficiency, longer life, better-looking equipment and at generally lower cost.

Supplying rolled steels in the complete range needed is our specialty. The list is imposing. U·S·S COR-TEN for corrosion resistance. U·S·S COR-TEN and U·S·S MAN-TEN for strength without excessive bulkiness or weight, U·S·S Abrasion Resisting steel for parts that need extra wear resistance. U·S·S Heat Resisting steel efficient under temperatures ordinarily disastrous. U·S·S Carilloy Alloy Steels for heavy bearing pressures.

Our steel specialists will be glad to show you how these steels can be used to best advantage. Their advice and assistance is yours without obligation. Why not check with them to keep abreast of the latest metallurgical improvements?

**USING THE RIGHT STEEL IN THE RIGHT PLACE**

**Man-Ten Crane Trolley weighs less.** *With tensile strength of 80,000 lb. per sq. in. min., and yield point of 50,000 lb. per sq. in. min.,* MAN-TEN *construction reduces weight far below conventional construction yet gives this trolley the safety that crane equipment demands.*



CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Export Company, New York

**UNITED STATES STEEL**

## ARC-WELDED PUSHER UNITS BUILT FOR HEAVY WORK

Alternating-current arc welding is used to considerable advantage by the Lewis Welding and Engineering Corporation, Cleveland, Ohio, in constructing pusher units for coal loaders. The more than 65 pieces of steel which go into the fabrication of one of these pusher units are accurately cut to shape before welding so that the completed unit will require a minimum of finish machining. The finished unit must be absolutely oiltight and capable of great strength and rigidity in order to withstand the heavy impacts and strains which occur during coal-loading processes. The oiltight feature is necessary for the housing to

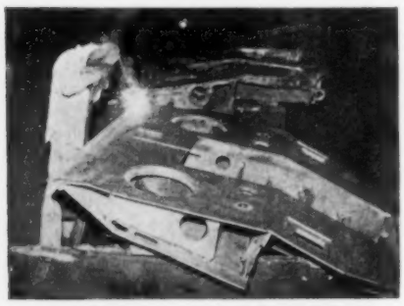


*Photo Courtesy General Electric Company*

two sets of gear trains which are fitted into the unit and used in operating it. The Lewis Welding and Engineering Corporation turns out four of these pusher units each month, welding all joints with the aid of 500-ampere a.-c. arc welders.

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## MECHANICAL CATALOG AND DIRECTORY

Of interest to engineers will be the news that the thirtieth annual A. S. M. E. Mechanical Catalog and Directory, 1941 edition, has just come off the press and is now being distributed to members of The American Society of Mechanical Engineers as part of their membership privileges. Non-members may obtain copies for the nominal sum of $3.00 each.

Hundreds of equipment and machinery manufacturers have contributed much information to this particular volume, thereby increasing its value more than ever in these days of preparedness and increased production to the engineer and manufacturing executive. The edition contains a profusely illustrated Catalog section describing machines, equipment and materials. This section is followed by a Directory in which is included a practically complete and authoritative index to all American manufacturers of metals and alloys, power-plant equipment, power transmissions, instruments, materials-handling apparatus, aircraft power plants, instruments, foundry and machine-shop equipment, heating, ventilating, and air-conditioning machinery, electric motors and controls, equipment for process industries, pumps, fans, compressors, and hundreds of other types of mechanical apparatus. A cross-reference plan enables the user to get a description of the desired machine or apparatus from the Catalog section of the 502-page book.

Also listed in the 1941 volume are hundreds of trade names of equipment and materials to aid the busy engineer. Since so many users of the book are interested in getting technical publications of the A. S. M. E., such as American Standards, power test, construction, and safety codes, fluid meters, engineering biographies, bibliographies, research reports and manuals, a 16-page insert listing these publications is included.

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## DR. SUITS NAMED ASSISTANT TO DIRECTOR OF G-E RESEARCH LABORATORY

Dr. C. Guy Suits, 35-year-old research physicist, has been appointed assistant to the director of the General Electric Research Laboratory.

The post is a new one and will permit Dr. Suits to continue his research while assuming some administrative duties, explained Dr. W. D. Coolidge, director of the Laboratory, in making his appointment.

Dr. Suits has been a member of the Laboratory staff since 1930 and is widely known for his research in high-temperature arcs. He has produced some of 18,000 degrees Fahrenheit, the hottest on record and twice the temperature of the sun's surface. Many of his 52 patents are in this field.

In the course of Dr. Suits' research on arcs, he developed a means of measuring their temperature by photographing sound waves passing through them. His work on the subject has helped in the understanding of welding arcs and has contributed to the development of more effective circuit breakers for the protection of power lines.

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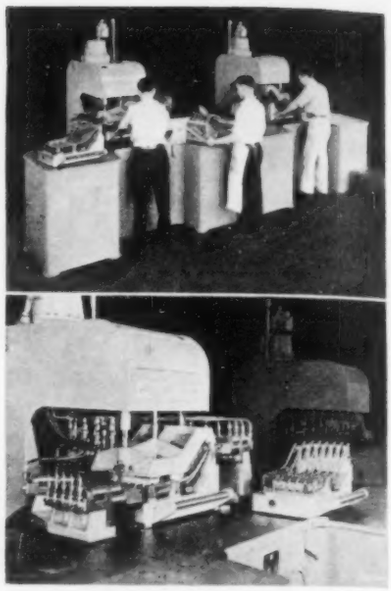
## WELDING JIGS

Newest development in the battle between die casting and assembly spot welding for complicated units is a process created for a leading automobile company for assembling its 1941 radiator grilles.

With this rather unique equipment which was designed and built by Progressive Welder Co., 3034 E. Outer Drive, Detroit, Michigan, some 1000 stampings are being assembled with 4000 spot welds into 100 complete radiator grille halves per hour.

Features of this equipment are:

1. Use of rubber-tired movable jig fixtures which are the lower electrodes during welding.
2. Multiple spot welding in series with 20 "guns" per station, each having two self-equalizing tips—2 welds per gun. Equal pressure also to all welding guns through use of a Progressive Hydr-O-Matic welding unit.
3. Completely automatic machine operation including automatic locating of the movable jig and welding.
4. Hand clamping of work is entirely eliminated.
5. Entire sequence of operations—for



loading parts into jig, and unloading for both radiator grille halves—requires but 5 by 12 feet of floor space.

The machine has two dual welding stations and two jigs mounted on rubber-tired wheels are used with each station. Each station is manned by two men. Each man handles one of the movable jigs which he loads, shoves into machine for welding and pulls out for unloading. Thus while one operator is loading his jig the second operator is welding the parts on his jig, and vice-versa.

In operation, a jig is loaded with the component parts of a grille half and is then moved into welding position. Guides and locking pins mounted on the table locate the fixture. When the wedges of the upper electrode descend they clamp the work held in the lower electrode securely in position. An air-operated clamp, which is the same form as the grille, presses the work in place on the welding jig and clamps the latter firmly on the table. This compresses springs which support the wheels and permits locating pins at either end of the jig to engage locating holes.

While production of 100 grille halves per hour is expected to fulfil requirements, it is possible to step up production by adding additional loaders at each station, no changes in the machine itself being required.

The equipment is shown in the accompanying illustration. The upper figure shows two welding stations with two men per station each loading, welding and unloading work. The lower portion shows one automobile radiator grille half jig clamped in welding position. The alternate jig is shown with welded part ready for rapid removal.

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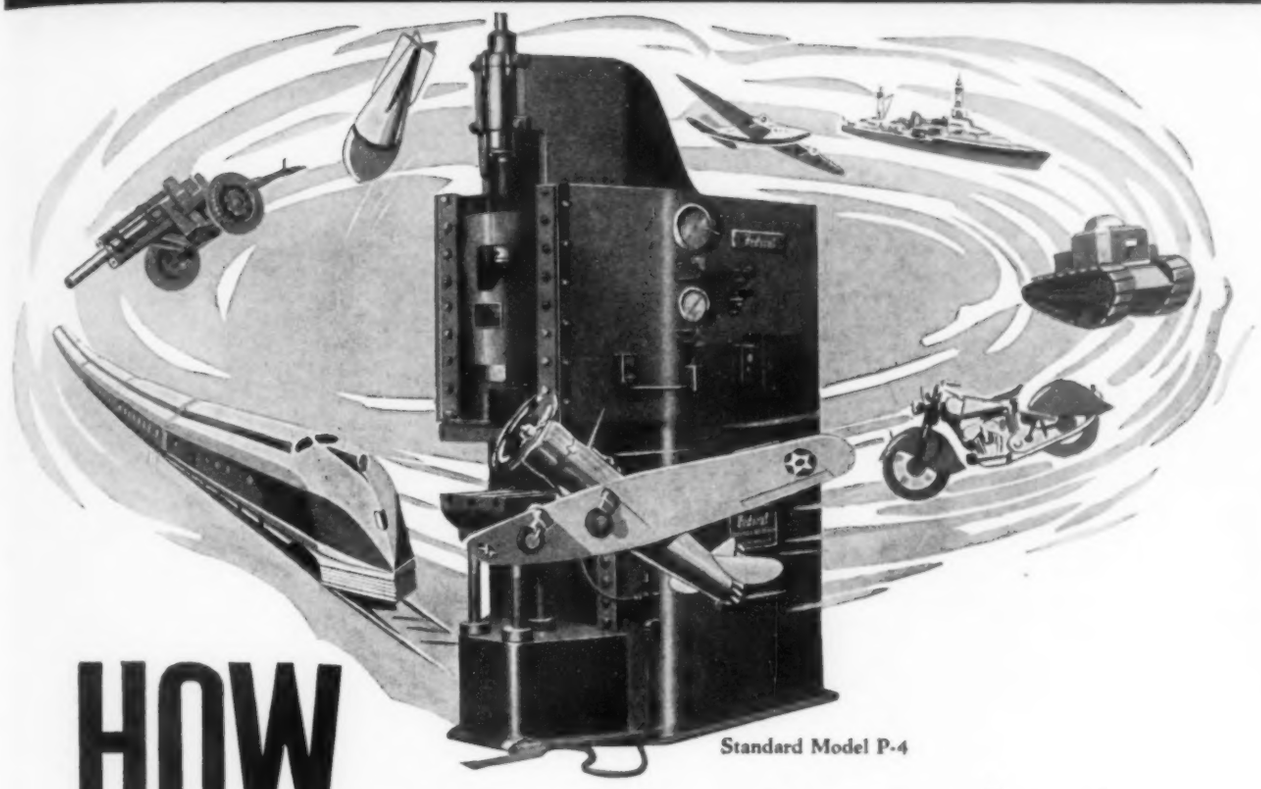
## PRACTICAL LESSONS IN ARC WELDING

This book sells for 50¢ and is used in the Hobart Welding School as well as hundreds of leading trade schools, colleges and technical institutes, as a text

## Always Consider Resistance Welding



Standard Model P-4

# HOW *are you planning production to meet National Emergency Demands?*

**This question faces every American manufacturer. Industry is now confronted with the moral obligation of providing material for national defense NOT in place of, but IN ADDITION to its regular production. This means that thousands of industries find themselves facing new production problems many of which will have to do with the fabrication of both ferrous and non-ferrous metals.**

**Federal Resistance Welding Machines of conventional or special design, are serving almost all industries, both large and small, in meeting current production requirements. Consider Resistance Welding and its broad potential possibilities, therefore, as a modern means of fabricating new products or increasing regular production in your particular industry.**

**Federal engineers, with many years of experience in "fitting the machine to the job," offer their services in a consulting capacity without obligation. Federal, too, has a job to do in the National Defense Program and considers such service in its line of national duty.**

Federal

## MACHINE & WELDER CO.

In England, made by British Federal Welder & Machine Co. Ltd., Dudley, England

WARREN, OHIO

SALES OFFICES IN ALL PRINCIPAL CITIES

book covering practical lessons in arc welding. Copies may be obtained from The Hobart Brothers Company of Troy, Ohio.

## AIRCO ANNOUNCES COURSE IN OXYACETYLENE WELDING AND CUTTING

A comprehensive course of classroom exercises and lectures covering the oxyacetylene welding and cutting processes has just been prepared by Air Reduction, New York. The course consists of two separate books, one containing a complete set of work sheets, and the other lecture material to be used as a supplement to the first.

The book covering classroom exercises is intended to impress the fundamentals upon those who are interested in gaining a working knowledge of the art. Its 22 chapters describe the practice of both oxyacetylene welding and cutting.

The course of lectures, although printed in a separate book, works in close conjunction with the student exercises. It describes the history of the art, the properties of its materials, its theories and its practical applications in industry. The book has been prepared so as to broaden the horizon of the student of the oxyacetylene process and to insure intelligent application of the manipulative skill he is attaining.

The course of classroom exercises sells for 50¢ per copy—lecture book are $1.00 each. Copies may be obtained by writing Air Reduction Sales Co., 60 East 42nd Street, New York, N. Y.

## QUICKER TRANSPORTATION FOR POWER SHOVELS

Most purchasers of "Bay City" shovels also purchase special "Haulaway" trailers to facilitate moving the shovels from one job to another. In the foreground of this view in the plant of Bay City Shovel Co., Bay City, Michigan, is a partial view of the trailer, built of arc-welded steel channels and deck plates, the openings at the end being provided for the trailer wheels. Arc welding is also used for fabrication of parts of the shovel itself, some of which are shown in the background.

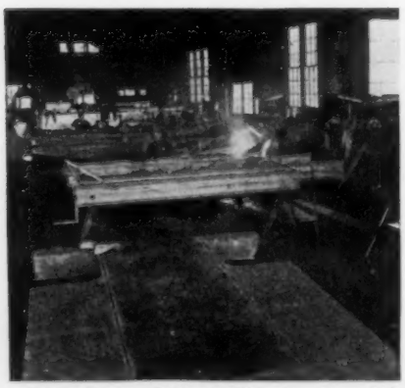


*Photo Courtesy Hobart Brothers Co., Troy, Ohio*

## ARC-WELDED STEEL JIGS FOR ARC-WELDED STEEL BODIES

Fruehauf Trailers, Detroit, Michigan, arc weld the frame work for trailer bodies in special jigs that are themselves of arc-welded steel construction. Four welding operators and two helpers work on each jig. Here is shown the fabrication of a body side panel framing.

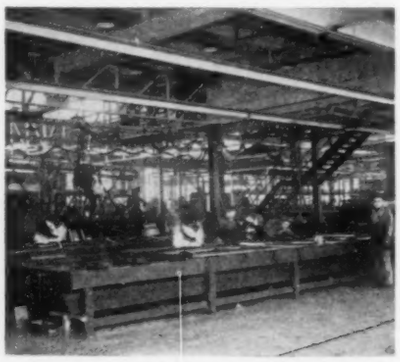


*Photo Courtesy Hobart Brothers Co., Troy, Ohio*

## ARC-WELDING HANDBOOK

Arc-Welding Handbook, by Karl Meller, 1940, price $3.50. Translated by J. E. Webb Ginger. The object of this handbook is to enable the operator to understand the processes involved in arc welding, and to utilize the results of the latest research in improving and simplifying his work. It will also be found useful to foremen and others entrusted with the training of welders, and of assistance in assessing their progress. The welding engineer will derive considerable interest from the descriptions of plant and equipment, and more especially from those pages devoted to the choice and testing of electrodes. Owners of small shops, who are frequently thrown entirely upon their own resources, will find invaluable information and advice in this handbook.

## HOW TO ASSEMBLE A WELDING OR CUTTING UNIT

With the tremendous increase in welding and gas cutting brought about by the accelerated armament program, thousands of beginners are now attempting to acquaint themselves with the equipments used and the processes employed in welding and cutting.

To give aid to the student and to the beginner, Victor has now issued a small booklet confining itself entirely to an understandable description of "How to Assemble the Welding and Cutting Unit." Large, full-page illustrations (5 x 7 inches) clearly visualize each step.

Three pages of "Simple Safety Precautions" and three pages of "Tip Selection Charts" are included. This booklet will be furnished free of charge to any vocational school or college and to any student or beginner who will write for it.

The booklet is issued by Victor Equipment Company, 844–50 Folsom Street, San Francisco, California, and is also obtainable through any authorized Victor distributor.

## SPECIAL FLOAT FOCUSES ATTENTION ON WELDING

A special float, which was planned and built by boys and girls of the National Youth Administration of Sullivan, Indiana, and which was a feature of a recent parade there, emphasized the important part of welding in present and future industrial developments.

The float, shown in the accompanying illustration, was devised to represent industrial operations and welding as covered in training courses of the NYA project, according to Bruce Collins, superintendent of the project.

*Photo Courtesy Lincoln Electric Co.*

The students started with an old truck, cut papier-mache into strips and did all the work involved in decoration. Mounting the welder on the float, tended by a youth attired in head shield and equipped with electrode holder, drew attention to welding, while young girls engaged in sewing and other occupations indicated that NYA training concerns young women as well as men.

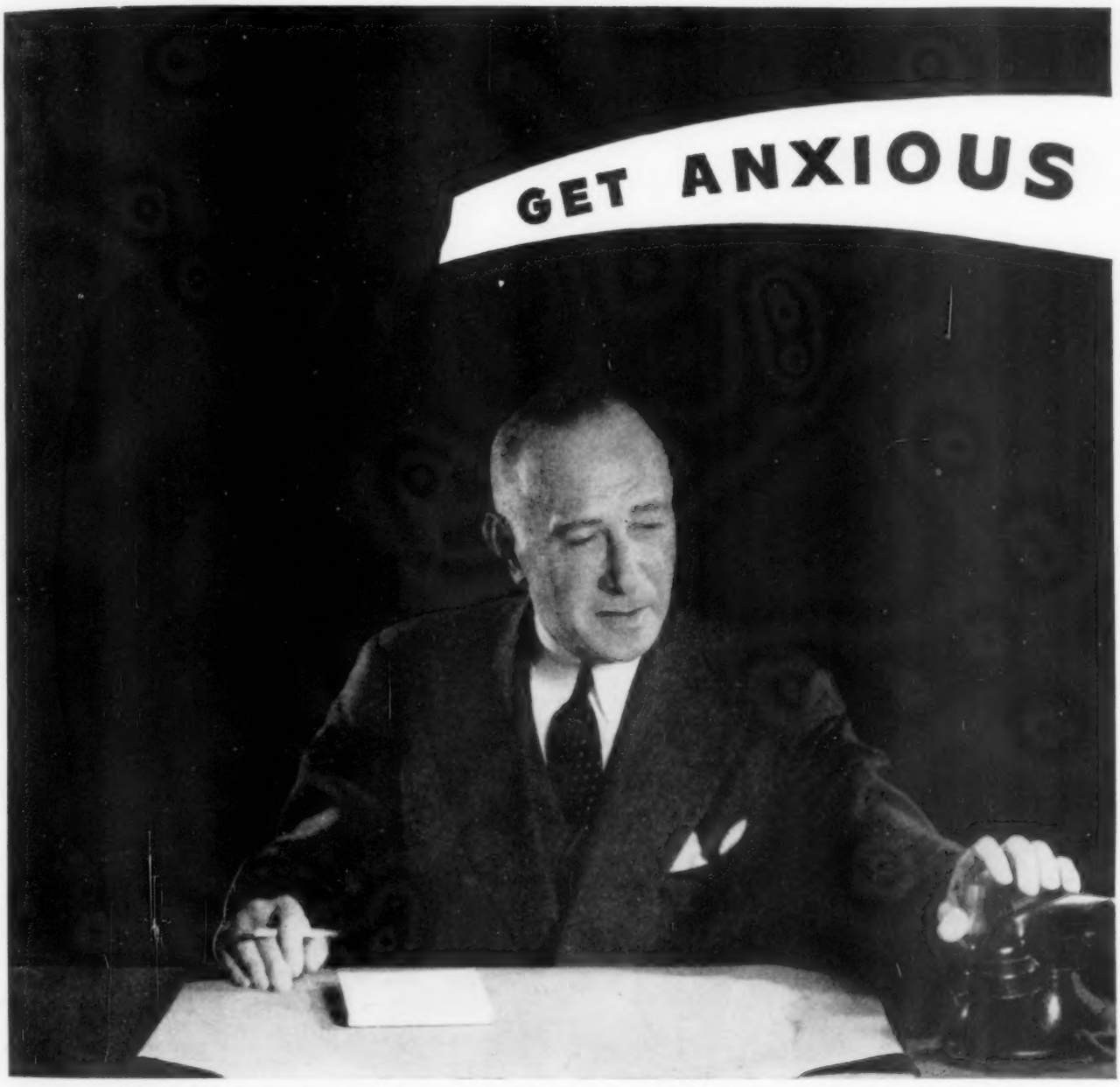
Welding machines provide NYA the means of teaching young men to weld and sufficient training is furnished to enable the graduates to hold a job. After a student completes the course, the NYA makes every effort to place him in a position.

Training is also given in the operation of other industrial machines such as lathes, shapers, etc., for metal working, as well as morticers, routers and hand tools for work in wood.

## RUMANIAN WELDING SOCIETY

Since its founding on June 19, 1937, the number of members in the Rumanian Welding Society has risen from 21 to 69 (July 1940). The Society has engaged in three activities:

(*a*) Research on the field welding of rail joints. Gas, arc and resistance welding have been studied by the Society. Gas welding was performed on rails (81 lb./yard) using 4 lb. of medium-carbon steel rod and $^1/_2$ lb. of high carbon steel rod per joint, which occupied 1 hr. The flash welding was performed at night and 1.2 inches of rail were flashed away in making each joint. The pulsating bend fatigue




ALTER EGO: Literally "one's other self"—the still, small voice that questions, inspires and corrects our conscious action.

**ALTER EGO:** Can't you make up your end of our mind to settle on Lincoln machines?

*Not yet, because I can't be sure that two controls on arc welders are necessary.*

**ALTER EGO:** How can you possibly be sure when you don't understand?

*But, I hear that other machines do well with just one control.*

**ALTER EGO:** Listen, when a man no longer is *anxious* to do better than WELL—he's done for.

*All right. For the sake of argument, call me anxious.*

**ALTER EGO:** OK—now let's put it up to Lincoln.

• •

LINCOLN SUGGESTS: Dual Continuous Control of "Shield-Arc" Welders is the ONLY WAY to fit the arc to the job—and to do each job the way it should be done. Its "Job Selector" gives you any TYPE of arc. Its Current Control gives you any arc INTENSITY. Result: You get maximum welding speed and maximum weld quality at all times. This new arc welding technique—what it means to *you*—is explained clearly in Bulletin 412.

**LINCOLN "SHIELD-ARC" WELDING** THE LINCOLN ELECTRIC COMPANY Cleveland, Ohio

*Largest Manufacturers of Arc Welding Equipment in the World*

strength of a flash-welded joint was found to be over 34,000 lb./in.$^2$, (2 million cycles, lower stress = zero). The time occupied between completing one joint and completing the next was 26 minutes.

(*b*) Organization of courses of instruction for welders. A course of lectures (2 volumes) has been written by Dr. C. Miklosi, and nearly 100 students have attended the courses.

(*c*) Publication of a quarterly welding magazine, about 500 copies of which are distributed every three months.

## ROAD WIDENER REPAIR

The scarifier teeth on a road widening machine which is used to cut down the berm along concrete roads in preparation for widening them with concrete, asphalt or other material, get plenty of wear. The gravel along the berm becomes impacted from cars that drive off the road and farm machines in transit, making it hard to penetrate and tough to dig up.

A highway engineer in charge of equipment was experiencing fast tooth wear on the machine shown widening a road 4 feet on each side to convert a 2-lane into a 3-lane highway. This widener has eleven rows of teeth, 1 1/2 inches wide and 3/4 inch thick which work most efficiently when they are sharp.

*Photo Courtesy American Manganese Steel Division*

To keep them sharp and to obtain reasonably long life at low cost is a problem which has been solved by hard facing, as has been done in so many cases where unavoidable abrasion has resulted in costly wear and operating delays. In this case a hard face which would provide both hardness and toughness was necessary. Low cost of welding material and application was also a factor. The material applied could not be so hard as to be brittle nor so soft as to be no better than the base metal.

A self-hardening rolled chromium-molybdenum-high-carbon steel welding rod with a Brinell of 450 to 550, was applied. The teeth gave far greater service after hard facing, averaging three times as many miles before they became worn to an extent that they were inefficient.

This is just another example of how hard-facing tools and equipment parts subjected to impact and abrasion can save for road builders and the various county, state and federal highway and other departments using road building and engineering equipment.

## PROCEDURES FOR WELDING ALL METALS

"The Lincoln Weldirectory," published by The Lincoln Electric Co., Cleveland, Ohio. 58 pages, 8 1/2 x 11 inches, 165 illustrations including photos and drawings, cover—printed in two colors.

Procedures for producing all types of welds in mild steel, for welding all metals used to any extent industrially and for applying surface metal to meet any type of wear-action in service, are given in this new bulletin just received from The Lincoln Electric Co., Cleveland, Ohio.

"The Lincoln Weldirectory" gives complete-procedures for the following: flat, vertical or overhead welding of mild steel; single or multiple pass welding and for poor fit-up in mild steel; flat welding of fillet welds in mild steel; flat welding of deep-groove joints in mild steel; flat welding of deep-groove joints in high tensile steels; general welding of high tensile steels; welding of light-gage steel, 18–8, 25–12, 18–8 SMO and 25–20 stainless steels, 4–6 chrome steels, chromium molybdenum, nickel chrome alloys, high manganese steel, cast iron, aluminum, bronze, brass and copper; for surfacing to produce moderate shock and abrasion-resisting welds; rolling or sliding abrasion-resisting welds; and for making tool steel cutting edges on ordinary steel and rebuilding worn tools and dies.

Properties of welds produced in various metals are given and typical welding applications are illustrated.

## GERMAN ELECTRIC WELDING SOCIETY*

The report of the German Electric Welding Society for 1938 and 1939 opens with a statements of its four objectives:

1. Supporting courses of instruction in electric welding for engineers and welders,
2. Publication of appropriate text books,
3. Supporting electric welding research in cooperation with the welding research committee of the German Engineers Society (VDI),
4. Representing electric welding among regulatory bodies, such as the boiler inspection society, railways and safety organizations.

There were 458 members on December 31, 1939, as follows:

| | |
|---|---|
| Societies and regulatory bodies | 58 |
| Electric power stations | 36 |
| Companies | 109 |
| Personal members | 255 |

There are nine technical committees on the following subjects: (1) apparatus, (2) filler metal, (3) power supply, (4) boilers and pressure vessels, (5) construction of vehicles, (6) construction of machinery, (7) shipbuilding, (8) bridge and structural, (9) spread of information. The Society cooperates with 31 schools for electric welding, attended in 1938 by 4760 students, and takes part in qualifying welders.

Standards have been issued in 1938 and 1939 on rules for welding generators and transformers, and on masks. The substitution of stress-relief heat treatment for normalizing of welded pressure vessels requiring national approval was made possible by research and discussion by Society members. Flash- and arc-welded joints in concrete reinforcing bars are designed on the basis of 60% of base metal strength, in accordance with agreements among the Society, the German Reinforced Concrete Association, and others.

## NEW TESTING METHOD FOR THIN SHEETS OF STAINLESS STEEL

Information on the compressive properties of very thin sheets of stainless steel is now being obtained at the National Bureau of Standards, Department of Commerce, through a new testing method developed by experts of that agency. The development of this special test was part of a research project undertaken for the National Advisory Committee for Aeronautics, supported by funds from eight different manufacturers. According to Dr. Lyman J. Briggs, Director of the Bureau, knowledge on how this material will behave under high compressive stress should increase its use in the manufacture of airplanes and may help to appreciably speed up airplane production.

The making of a compression test on a very thin sheet of metal is a difficult procedure because the specimen buckles under stresses much less than the maximum compressive strength of the material. Yet accurate information on the compressive properties is essential for a safe and at the same time light and economical design. The problem was solved by building up a test specimen of many pieces placed side by side similar to a pack of playing cards. These pieces are cemented together with shellac and are supported in such a way as to prevent buckling laterally as the load on the testing machine is increased. Using this method, sheets of the metal two one-thousandths of an inch thick have been subjected to loads of 110 tons per square inch.

Stainless steel possesses high strength and is very resistant to corrosion. With a full knowledge of its compressive properties, engineers need no longer hesitate to consider the use of this widely available material for aircraft and other lightweight structures.

* Abstract of "Tätigkeitsbericht der Deutschen Gesellschaft für Elektroschweissung E. V." published in *Elektroschweissung*, 11 (6), 106–108, June 1940.

*You merely*

# DIAL for Better Welds

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• Adjusting a Weltronic Weld Timer to the exact weld time required for any work is as simple and rapid as touching a station selection button on your modern radio to "bring in" another program.

Weltronic's positive electronic timing control adjustment is almost instantaneous and yet it provides the widest range of rapid timing selection.

Once adjusted to the exact timing your work requires, Weltronic timers provide absolute accuracy throughout an unlimited number of welds.

There are no cams, gears or other mechanical timing mechanisms to wear out. Re-adjustment to compensate for wear of moving time elements is *entirely eliminated* in a Weltronic Timer.

Fast, foolproof adjustment of weld time to the finest gradation required is a feature of Model 55. Low cost and positive in operation, this single tube, single relay timer provides weld, off and automatic repeat welding control for high speed single or multiple spot welding.

•

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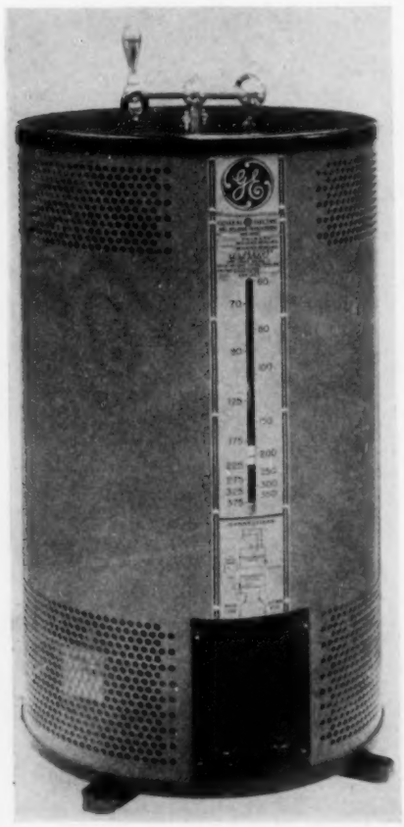
# NEW PRODUCTS

**The Society assumes no responsibility for the validity of claims in this Section**

## 300-AMPERE A.C. WELDERS

The General Electric Company has added a new 300-ampere size to its line of arc-welding transformers with built-in power-factor correction. As in the 500-ampere welder previously announced in this line, this new size offers all the advantages of high power-factor without sacrifice of stability or performance. Not only is useless lagging current practically eliminated under load, but at light loads or no load, power-factor correction for other plant load is provided. Smaller line cable, line switches and fuses can thus be used. This often results in savings on



installation costs or makes possible the addition of more welders to existing feeders without causing overload.

Other advantages of this new 300-ampere welder include: finger-tip current adjustment; large, easily read current indicators; protected output terminals; and fan-forced ventilation. The refinement of design permits reduction in size, weight and floor-space requirements. Thus the new welder is only 43 inches in height, only 21 inches in diameter and has a net weight of only 450 pounds.

## NEW AUSTENITIC, TOUGH, NON-MAGNETIC STEEL

Manganal—an austenitic, tough, non-magnetic steel containing 11 to 13½% manganese and 3½% nickel—is now carried in stock for immediate shipment by Joseph T. Ryerson & Son, Inc.

In making available a non-magnetic, abrasion-resisting steel which can be welded, a real industrial need has been filled. For example, considerable weight can be saved in building composite structures by welding castings and Manganal plates, using Manganal only where necessary for wear resistance.

The 3½% nickel content permits Manganal plates to be welded without a subsequent quenching treatment as there is no loss in toughness when Manganal is cooled from the welding temperature. This makes a reasonable structural material of a composition that otherwise is difficult to handle. Welding rod of 18–8 stainless composition has been found to give very satisfactory results when used with Manganal.

Manganal has all the advantages of 11–14% manganese steel in resistance to wear and surface work hardening. Thicknesses up to ½ inch can be sheared. Manganal can be flame cut, and requires no subsequent heat treatment when formed or punched hot. This characteristic gives Manganal a distinct advantage over 11–14% manganese steel which must be given a full heating and quenching treatment after forming if the original toughness and ductility is desired—a treatment which often distorts the formed shapes.

Chemical composition and physical properties of Manganal are:

Carbon, 0.60 to 0.90.
Manganese, 11 to 13½%.
Silicon, 0.60 to 0.95.
Nickel, 2.50 to 3.50.
Tensile strength, 140,000 to 150,000 lb. per sq. in.
Elastic limit, 55,000 to 60,000 lb. per sq. in.
Elongation in 2 inches, 72½%.
Reduction of area, 54%.

Hot-rolled Manganal plates are currently being used for electrical applications where non-magnetic characteristics rather than abrasion resistance are required. Welders are successfully using Manganal for patching broken and worn-down parts made from 11–14% manganese steel. It is also being used as a substitute for heavy castings where weight reduction is important. Manganal is strong and durable, and under proper application will resist impact and abrasion many times longer than ordinary carbon steel. Typical applications include journal boxes, pedestal liners, wear plates, mill liners, shovel buckets, conveyors, crusher hammers, etc.

Hot-rolled Manganal steel is carried in stock by Ryerson in 48 x 120-inch plates in the following thicknesses: 3/16, 1/4, 3/8, 1/2, 5/8, 3/4, 1 inch.

## AIRCRAFT ELECTRODE

Two important new applications of the electric arc in aircraft structural welding have been prompted by the urgent necessity for fast production in National Defense.

These new uses for arc welding include fabrication of engine mounts and landing gear forks and other applications.

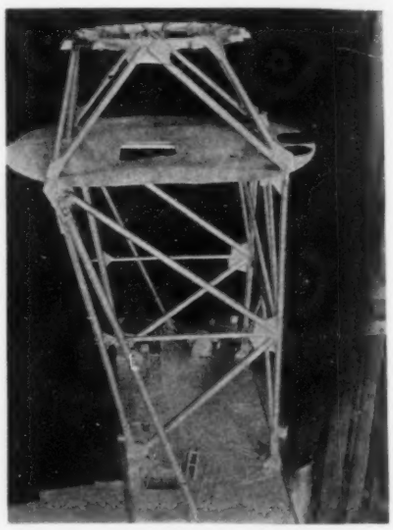
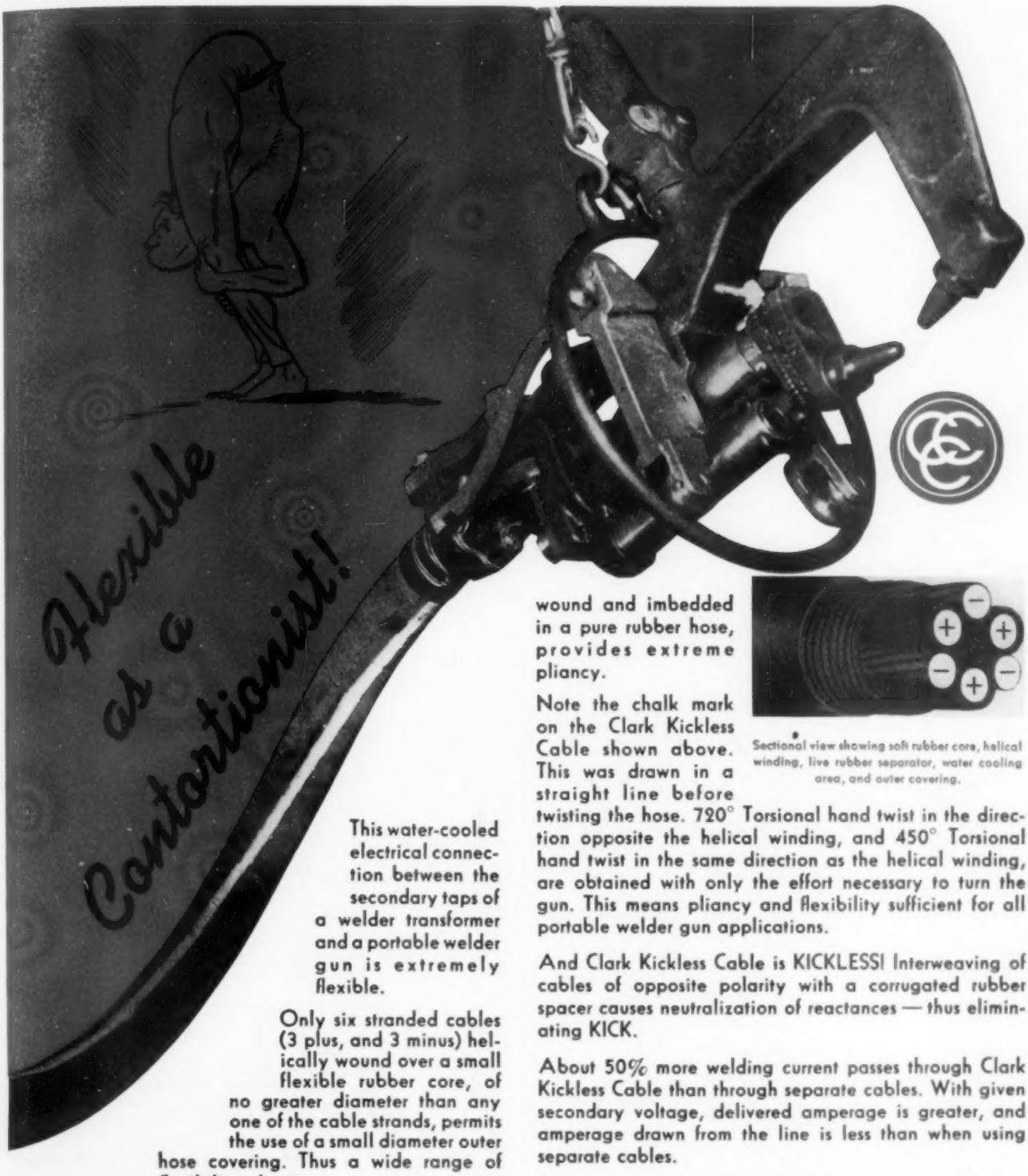


**Fig. 1—Airplane Engine Mount Fabricated by Arc Welding Using New Electrode Developed Expressly for Aircraft Welding**

Both have been made possible by development of a new electrode designed and manufactured by The Lincoln Electric Company, Cleveland, Ohio, expressly for plane welding. Known as "Planeweld," the electrode is of shielded arc type for

**Fig. 2—Airplane Landing Gear Fork Welded with New Special Arc-Welding Electrode**




This water-cooled electrical connection between the secondary taps of a welder transformer and a portable welder gun is extremely flexible.

Only six stranded cables (3 plus, and 3 minus) helically wound over a small flexible rubber core, of no greater diameter than any one of the cable strands, permits the use of a small diameter outer hose covering. Thus a wide range of flexibility obtains.

The specially constructed outer covering, made with long staple fibre cord which is helically wound and imbedded in a pure rubber hose, provides extreme pliancy.



Sectional view showing soft rubber core, helical winding, live rubber separator, water cooling area, and outer covering.

Note the chalk mark on the Clark Kickless Cable shown above. This was drawn in a straight line before twisting the hose. 720° Torsional hand twist in the direction opposite the helical winding, and 450° Torsional hand twist in the same direction as the helical winding, are obtained with only the effort necessary to turn the gun. This means pliancy and flexibility sufficient for all portable welder gun applications.

And Clark Kickless Cable is KICKLESS! Interweaving of cables of opposite polarity with a corrugated rubber spacer causes neutralization of reactances — thus eliminating KICK.

About 50% more welding current passes through Clark Kickless Cable than through separate cables. With given secondary voltage, delivered amperage is greater, and amperage drawn from the line is less than when using separate cables.

For better welds, less operator fatigue, longer cable life, less maintenance, greater accuracy, and consistent production use Clark Kickless Cable.

WRITE FOR FULLY DESCRIPTIVE BULLETIN 7777

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welding S. A. E.-4130 and X-4130 chrome molybdenum steels, which are widely used in airplane construction. "Planeweld" is suitable for welding in all positions and when used on steels of the types mentioned provides weld metal with physical properties similar to the metal welded. Its welds are smooth without undercutting. There are minimum spatter and good crater conditions and welds made by the electrode on such steels respond to heat treatment quite similar to the parent metal. Planeweld comes in two types—Planeweld No. 1 for material 0.120 inch and heavier, and Planeweld No. 2 for light gage airplane parts (up to approximately $^{7}/_{64}$ inch) and airplane tubing.

The new electrode which was developed to overcome difficulties formerly encountered in airplane welding is available in four sizes: Planeweld No. 1 in $^{1}/_{8}$ inch, $^{5}/_{32}$ inch and Planeweld No. 2 in $^{1}/_{16}$ inch and $^{3}/_{32}$ inch. It is suitable for welding airplane fuselages, tail supports, torque tubes, bomb mountings, alloy chain links, antenna mounts, chairs, as well as engine mounts and landing gear forks, or any other airplane part constructed of the steels mentioned.

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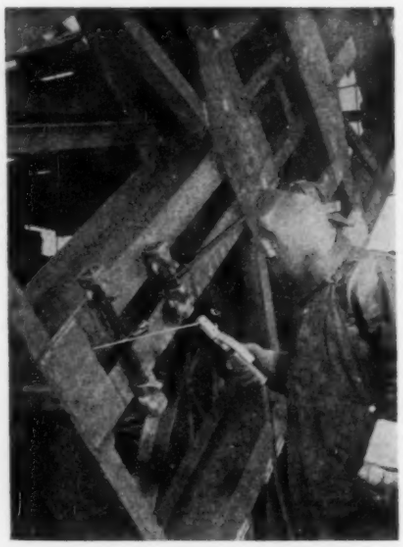
## WELDING OF BULKY PARTS

The Util-A-Tool introduced by Templeton, Kenly & Co., 1020 S. Central Ave., Chicago, may solve some of the problems experienced by welders in welding structural shapes and on reclamation and hard-facing welding.

The Util-A-Tool consists of 8 pieces of equipment used in various combinations in conjunction with a push and pull device. This consists of two lugged nuts on a forged steel screw fitted with a ratchet handle. Working the ratchet brings them together or moves them apart on the screw. The entire unit comes in a compact metal carrying case.

Three $^{1}/_{2}$ x 40-inch chains, part of the equipment, are used to bind pipe, beams, etc., to hold them in place for welding. For longer parts, such as the large cement mill gear shown, cable can be used.

**Pair of Util-A-Tools and Steel Cables Holding Broken Cement Mill Gear Parts Together for Welding**



**Holding Structural Members in Place for Welding. One is Pushing Apart and the Other Is Pulling Together. Most Jobs Can be Done with a Single Unit**

As the lugged nuts exert a direct pull or push of $17^{1}/_{2}$ tons, it may be seen that large and heavy members can readily be clamped or held in position for welding. As the facing lugs on the nuts can be brought as close together as $2^{3}/_{4}$ inches, the push and pull jack can also be used to clamp smaller parts. The push and pull devices from two Util-A-Tool kits can be effectively used to clamp structural frameworks, as shown, one pushing and one pulling to hold members in a predetermined position.

In addition to holding parts for welding, the Util-A-Tool can be used to bend pipe and structural steel or to straighten bent axles, pipe, etc. It also pulls plate center or spoked wheels, gears and pulleys and loosens frozen or stuck objects. The slip-on base provided enables the unit to be used as a standard 10-ton jack.

A bulletin, P & P 40, gives details on its construction and use.

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## SPOT WELDER

A complete line of air-operated rocker arm type spot welders in transformer capacities of from 10 kva. to 75 kva. is announced by the Acme Electric Welder Company of Huntington Park, California, and described in their new bulletin No. 52 available on request.

These spot welders come completely equipped with automatic weld timers and welder service magnetic contactors and are offered in various styles actuated by a foot valve and limit switch, by a solenoid-operated mushroom type floor switch or by a specially designed two-stage toe-operated floor switch. They are available in either single spot non-beat or automatic repeat operation.

Advantages offered by air-operated spot welders are faster production, uniform spot welds and the elimination of operator fatigue.

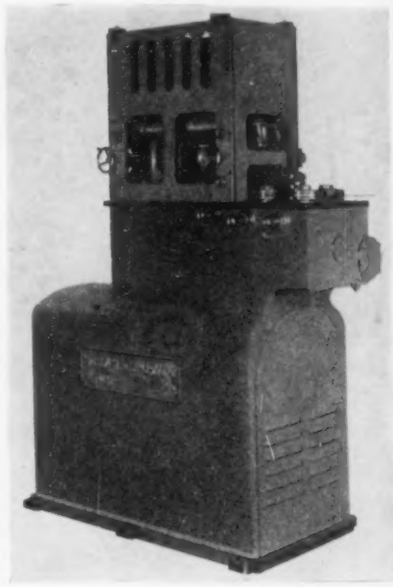
## ALUMINUM BRONZE ROD

Ampco Metal, Inc., Milwaukee, Wis. announces that aluminum bronze in the form of a coated weldrod is now being produced for the first time. The usefulness of the aluminum bronze alloys with their properties of wear resistance, high strength, hardness, and resistance to fatigue and corrosion, is thus extended to meet the demand for such a material.

---

## ROD HOPPER

A Welding Rod Hopper Feeding machine is announced by Moslo Machinery, Inc., of Cleveland, Ohio. Originally built for one of the larger welding rod manufacturers, the design of this machine proved so successful that it is now being built for general sale.



Prime purpose of the feeder is to pass straightened and cut wires of rods into an extrusion press for application of coating material to welding rods. Until now the problem of uninterrupted flow of rods into the extrusion presses has always been a serious one. The Moslo Hopper Rod Feeding Machine is reported to offer an adequate answer.

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## SPOT WELDER CATALOGUE

Condensed Spot Welder data are included in a new 4-page folder just published by the Pier Equipment Mfg. Co., Benton Harbor, Michigan, makers of Ace Spot Welders. Information on the manually operated types and on the automatic types is segregated with brief description concerning the applications of the various sizes made which run up to 50 kva.

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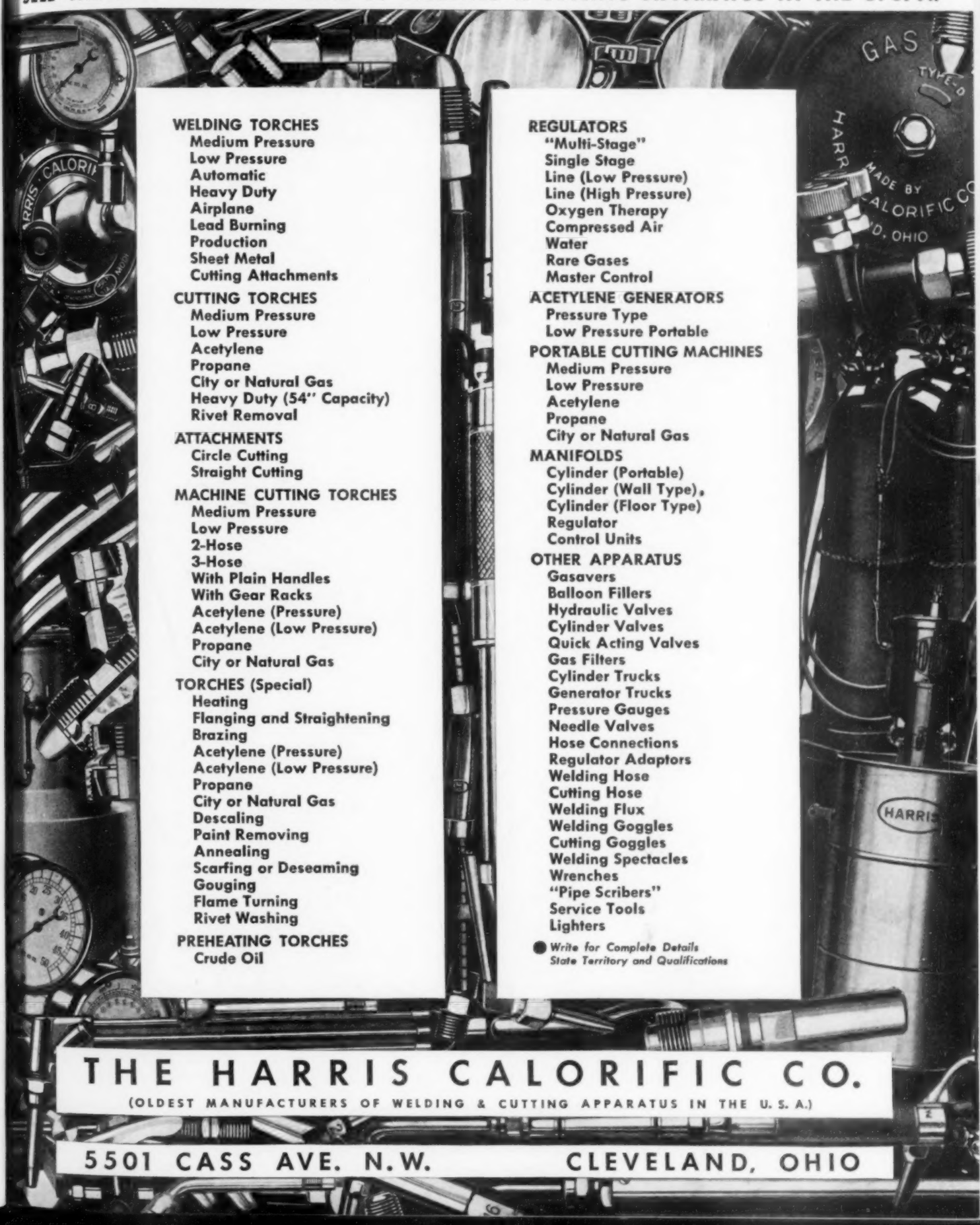


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# » » » SECTION ACTIVITIES « « «

## BIRMINGHAM

The Birmingham Section held its regular monthly meeting October 8th at 7:45 P.M. in the auditorium of the Alabama Power Company's Building, presenting as guest speaker Mr. W. D. Halsey, Assistant Chief Engineer, Boiler Division of the Hartford Steam Boiler Inspection and Insurance Company.

Mr. Halsey's talk, "Qualtfications of Welding Procedures and Operators and the Inspection of Welding," was a most timely and interesting subject and created a great deal of interest.

Mr. Halsey is especially qualified to handle this subject, having graduated from Swarthmore College, following which he obtained several years of practical experience in mechanical work in some of the largest manufacturing plants in this country. He at one time also spent a number of years as instructor and Professor of Mechanical Engineering in George Washington University; in 1920 joining the staff of the Hartford Company, and since that time he has acted in the capacity of Chief Editor of Publications, Assistant Chief Engineer and Assistant Chief of Boiler Division.

Mr. Halsey is also prominent in the affairs of the AMERICAN WELDING SOCIETY, being Chairman of the A. W. S. committees on Standard Qualification Procedure, and Pressure Piping, and is also a member of the committee on American Society Mechanical Engineers' Boiler Welding Code.

## BOSTON

The following is the program for the remainder of the 1940–41 season of the Boston Section:

Nov. 18th—Meeting Place: Massachusetts Institute of Technology, Room 4-270; 7:45 P.M. Speaker: C. J. Holslag. Subject: "The Welding of Carbon Molybdenum Pipe."

Dec. 9th—Meeting Place: Massachusetts Institute of Technology, Room 4-270; 7:45 P.M. Speaker: R. L. Briggs. Subject: "Resistance Welding."

Jan. 13th—Meeting Place: Massachusetts Institute of Technology, Room 4-270; 7:45 P.M. Speaker: Professor A. R. Anderson. Subject: "Welding in the Design of Bridges."

Feb. 10th—Meeting Place: Massachusetts Institute of Technology, Room 4-270; 7:45 P.M. Speaker: J. G. Magrath. Subject: "Flame Cleaning, Dehydrating and Descaling."

March 28th—Meeting Place: Lorimer Hall, Tremont Temple, Boston; 7:45 P.M. Joint meeting of the AMERICAN WELDING SOCIETY, the American Society of Metals and the American Institute of Mining and Metallurgical Engineers. Speaker: Dr. V. N. Krivobok. Subject: "The Welding of Stainless Steels."

April 11th and 12th—First New England Welding Conference. Chairman: Professor Peter E. Kyle, Massachusetts Institute of Technology, Cambridge.

Frank B. Mahaffey, Chairman, Boston Section

## CINCINNATI

The first regular monthly meeting of the 1940–41 season of the Cincinnati Section was held as a joint meeting with the A. S. M. and the A. S. T. E. The meeting took place at the Cincinnati Yacht Club aboard their fine new floating clubhouse.

Entertainment for the evening was furnished by Mr. E. E. Krieble, Bowles Sporting Goods Company, who gave a very interesting demonstration of plug and fly casting. Another very interesting event of the evening was motion pictures, furnished by Canadian National Railway, entitled "Fishing across Canada," by Courtney Riley Cooper, editor of *Field and Stream Magazine*.

## CLEVELAND

Our newly elected president, G. F. Jenks, Colonel, Ordnance Dept., U. S. Army, addressed the October 9th meeting of the Cleveland Section and his talk was enthusiastically heard by an audience of ninety weldmen following a dinner at the Mid-Day Club.

Program for the 1940–41 season of the Cleveland Section was given in the October Section Activities.

## COLUMBUS

The following are the subjects and speakers for meetings of the Columbus Section for the 1940–41 season:

Nov. 8—Dinner Meeting, Hotel Fort Hayes. Speaker: Chas. H. Jennings, Westinghouse Elec. & Mfg. Co. Subject: "Progress and Application of Welding in Foreign Countries."

Dec. 13—Dinner Meeting, Hotel Fort Hayes. Speaker: C. H. Jackman, Carnegie-Illinois Steel Corp. Subject: "Fabrication of Low Alloy Steels."

Jan. 10th—Battelle Memorial Institute. Speaker: F. R. Hensel, P. R. Mallory & Co. Subject: "Welding of Stainless Steels."

Feb. 14th—Dinner Meeting, Hotel Fort Hayes. Speaker: J. H. Deppeler, Metal & Thermit Corp. Subject: "Thermit Welding and Its Applications."

March 14th—Dinner Meeting, Hotel Fort Hayes. Speaker: K. L. Hansen, Harnischfeger Corp. Subject: "The Electric Arc as a Welding Tool."

April 11th—Dinner Meeting, Hotel Fort Hayes. Speaker: H. O. Jones, Air Reduction Sales Co. Subject: "Oxyacetylene Welding and Allied Processes."

May 9th—Battelle Memorial Institute. Speaker: R. F. Wyer, General Electric Co. Subject: "Atomic-Hydrogen Welding."

Dinner meetings start promptly at 6:45 P.M. Technical sessions start promptly at 8:00 P.M.

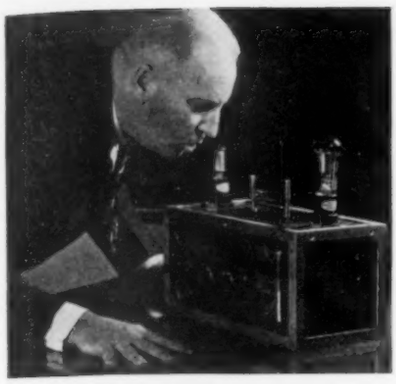
## DETROIT

At the opening meeting of the Detroit Section, which was held at the Colonial Room of the Detroit Leland Hotel on Friday, October 11th, there was an attendance of over 150. The speaker was Mr. George M. Chute of General Electric Co., the subject being "Controlling Resistance Welders by Electronic Tubes." The meeting was very interesting, and the questions which were brought up at the end of the talk proved conclusively that the audience was very much interested.

## INDIANA

Mr. A. C. Rasmussen is now Major Rasmussen of the Cincinnati Ordnance Department and because of his new duties he has had to resign as Chairman of the Indiana Section. Mr. Wayne H. McGlade, Assistant Chief Engineer of J. D. Adams Company, was elected the new Chairman. Vice-Chairman is C. I. Lundgren, local representative of the Taylor Winfield Corporation. Treasurer is Paul Grubbs, P. R. Mallory Company.

The first fall meeting of the Section was held on October 17th at the Spink Arms Hotel. The speaker was Dr. Phillips Thomas, Research Engineer, Westinghouse Elec. & Mfg. Co., whose subject was "Recent and Interesting Developments in Electrical Apparatus and Phenomena."



Dr. Phillips Thomas

Dr. Thomas uses thousands of dollars worth of especially built apparatus as well as motion pictures to demonstrate and illustrate this lecture. Some of the interesting subjects demonstrated were: Blowing Out the Electric Light, also Plastics, Photoelasticity, Silverstat, Magnetism, Invisible Light, De Ion Gap, Stroboscope, Sterilamp Radiation and others. A photograph of Dr. Thomas is shown above.

## KANSAS CITY

The second regular meeting held October 1st at the Ambassador Hotel had as guest speaker Dr. V. N. Krivobok, of the Allegheny Ludlum Steel Corp., Pittsburgh. Dr. Krivobok gave a talk on "The Character and Properties of Welded Stainless Steel" which was of great benefit to everyone attending.

The following is the program for the remainder of the 1940–41 season:

Nov. 12th—Dinner meeting, 6:30 P.M. Speaker: J. F. Lincoln, President of Lincoln Electric Co. Subject: "Welding Profits versus Prejudice." Slides.

Dec. 3rd—Meeting, 8:00 P.M. Speaker: A. S. Low, Austin Company. Subject: "Construction and Fabrication Dealing Especially with Welded Design."

Jan. 14th—Meeting, 8:00 P.M. Speaker: F. C. Hutchison, Mgr., Process Service, The Linde Air Products Co. Subject: "New Developments in Connection with the Use of Oxy-Acetylene Welding." Slides and motion pictures.

Feb. 4th—Dinner Meeting, 6:30 P.M. Speaker: W. G. Theisinger, Lukens Steel Company. Subject: "Heat and Mechanical Stress in Welding." The forming of heads for pressure vessels, slides and moving pictures.

March 4th—Dinner Meeting, 6:30 P.M. Speaker: J. D. Gordon, Gen. Mgr., Taylor Winfield Corp. Subject: "Spot and Resistance Welding." Slides and motion pictures.

April 8th—Dinner Meeting, 6:30 P.M. Speaker: O. T. Barnett, Black, Sivalls & Bryson, Inc. Subject: "Procedure Control of Welding." Motion pictures.

May 6th—Dinner Meeting, 6:30 P.M. Annual election of officers. Speaker: R. L. Lerch, Haynes Stellite Co. Subject: "Hard Facing." Moving pictures.

## LOS ANGELES

Mr. David P. Bisbee, production superintendent of the Rheem Mfg. Co., practically conducted a one-man session at the October meeting. He gave an instructive talk on the production of light steel containers such as barrels, drums, water tanks and range boilers. The group then adjourned to the Rheem Mfg. Co. plant to see the production equipment actually in operation.

Since it has been definitely assured that the Western Metal Congress will be held in Los Angeles next March, the Los Angeles Section has formed the necessary operating committees to see that the Congress will be one of the most successful ever held. The following tentative committee chairmen have been appointed:

| | |
|---|---|
| Program | Jim Gowing |
| Exhibitor | Clarence Sander |
| Publicity | Ed Williams |
| Registration | Merrill Turner |
| Entertainment | J. C. Blake |
| Coordinating chairman | P. D. McElfish |

## MILWAUKEE

The October meeting held on the 18th was a dinner meeting held at the Republican Hotel. An after-dinner talk was given by Scott Leavitt of the United States Forest Service, who spoke on "Rebuilding the Forests." The welding address on "Welding of Low-Alloy Nickel Steels," was given by T. N. Armstrong of the Development and Research Division, International Nickel Co. Mr. Armstrong discussed and illustrated the welding characteristics of low-alloy steels of the S. A. E. types and the constructional high tensile low-alloy nickel, copper steel.

The next meeting of the season will be held on November 15th. Dr. W. A. Pearl, Armour Institute of Technology, Chicago, will speak on "Weld Zone and Pre- and Post-Welding Stresses."

## NEW YORK

The opening meeting for the 1940–41 season of the New York Section, held Tuesday evening, October 8, 1940, in Room 502 of the Engineering Societies Building, took the form of a Questions and Answers program.

Mr. Everett Chapman, President of Lukenweld, Inc., as chairman of the technical session very ably propounded the questions to a Board of Experts consisting of Messrs. R. H. Aborn, J. J. Crowe, J. H. Deppeler, G. D. Fish, A. B. Kinzel, J. T. Phillips, H. E. Rockefeller, G. V. Slottman, T. B. Smith, Wm. Spraragen and J. L. Wilson. Besides the problems submitted in advance many technical questions were raised by members in the audience, and the answers of the experts evoked exceptionally interesting discussion. The members voted to hold a similar meeting next year.

In spite of inclement weather an attendance of nearly one hundred was recorded. Following the discussion, announcement was made of the New York Section's Fifth Annual Series of Lectures, which will begin in November, and after adjournment refreshments were served.

The November 12th meeting of the Section will be a joint meeting with the American Society of Mechanical Engineers, Metropolitan Section, and the topic will be "Cutting and Welding in Machinery Fabrication."

## NORTHWEST

R. H. Newton, chairman of the program committee of this Section, has arranged an exceptionally fine schedule of meetings for the current year. The dates, speakers and subjects are shown below:

Nov. 7th—Louis J. Larson, Consulting Welding Engineer, Milwaukee, Wisconsin, "Mechanics of the Arc."

Dec. 12th—D. H. Corey, The Detroit Edison Company, Detroit, Michigan, "Pipe Welding."

Jan. 9th—Elmer E. Isgren, Plant Superintendent, R. G. LeTourneau, Inc., Peoria, Illinois, "Construction and Fabrication."

Feb. 11th—H. C. Hettelsater, Standards Engineer, Harnischfeger Corporation, Milwaukee, Wisconsin, "Designing Material Handling Equipment for Production by Welding."

Mar. 10th—John D. Gordon, General Manager, The Taylor-Winfield Corporation, Warren, Ohio, "Modern Resistance Welding."

Apr. 22nd—Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Corporation, Pittsburgh, Pa., "The Elements of Welded Design."

May 21st—F. L. Plummer, Chief Research Engineer, Hammond Iron Works, Warren, Pa., "Welding Applied to Structural Buildings and Bridges."

In addition, the Section will undoubtedly hold special meetings during the season, which will be addressed by other speakers recognized as authorities in their respective fields.

## OKLAHOMA CITY

The October 3rd meeting of the Oklahoma City Section was a dinner meeting held at the Biltmore Hotel. Dr. V. N. Krivobok, Allegheny Ludlum Steel Corporation, addressed the gathering on "Characteristics and Properties of Welded Stainless Steels," which was illustrated with motion pictures and slides.

## PHILADELPHIA

The regular monthly meeting of the Philadelphia Section was held on October 30th at the Engineers' Club. A new and interesting subject, "Flame Machining Control and Applications," was presented by Mr. W. G. Sylvester of the Air Reduction Sales Company.

The next meeting of the Section will be held on November 18th. Mr. J. E. Waugh, of the General Electric Company, will speak on "Welding of Low Alloy Steels."

## PITTSBURGH

The opening meeting of the Pittsburgh Section was held October 16th in the Mel-

lon Institute of Industrial Research, where 126 members and guests heard Mr. L. C. Bibber, Welding Engineer, Carnegie Illinois Steel Corp., deliver his lecture on "Elements of Welded Design," a talk dealing with the various types of connections—flexible, three-way, tangent, box-type, doublers, etc., all of which were clearly illustrated with many excellent slides. Mr. Bibber is a particularly forceful speaker and presented his lecture in a manner which left no room for doubt as to his mastery of the subject. Following the talk a discussion of nearly an hour ensued during which many interesting questions were asked by those present and were satisfactorily answered by Mr. Bibber.

## PUGET SOUND

A dinner meeting was held on October 14th by the Puget Sound Section. Mr. William Flint showed a film, "The Design of Steel Castings," which was edited and presented by the Steel Founders Society of America, with sound accompaniment.

## ROCHESTER

The educational course given by the Rochester Section began Thursday evening, October 10th at 7:15 P.M. in Room 208, Engineering Building, University of Rochester, River Campus. The lectures will be devoted to the fundamentals of metallurgy as related to welding. The second and third lectures were given on October 17th and October 31st. The remaining lectures and their dates will be as follows:

"Bearing Alloys," Nov. 14th; "Cast Iron, General," Nov. 28th; "Cast Iron, Special," Dec. 12th; "Cast Steel," Dec. 19th; "Ingot and Wrought Iron," Jan. 9th; "Low and Medium Carbon Steel," Jan. 16th; "Low Alloy Steel," Jan. 23rd; "Low Alloy Steel," Jan. 30th; "High Alloy Steel," Feb. 13th; "High Alloy Steel," Feb. 20th; "Stainless Iron and Steel," Feb. 27th; "Special Steels," Mar. 13th; "Failures as Related to Structure," Mar. 20th; "Corrosion as Related to Structure," Mar. 27th; "Problems in Welding," Apr. 10th; "Problems in Welding," Apr. 24th.

The course is free to members. For non-members the fee is $5.00.

## ST. LOUIS

Mr. O. T. Barnett, Chief Metallurgist of Black, Sivalls & Bryson, Inc., was the guest speaker at the October 18th meeting held in the Engineers Club Auditorium. Mr. Barnett presented an illustrated lecture on "Procedure Control in Welding" as applied to low carbon steels, high-tensile steels and some special alloys used for particular welding problems. Mr. Barnett supplemented his lecture with a natural color motion picture covering the manufacture of oil and gas separators.

## SAN FRANCISCO

The San Francisco Section of the AMERICAN WELDING SOCIETY is giving a course of lectures and discussions covering the principles of the Fusion Welding Process. The course itself has been carefully prepared by leading members of the Section and will be given under the direction of Professor N. F. Ward of the University of California. They will be given on Monday nights, from October 14, 1940, to February 10, 1941, from 7:30 P.M. to 9:00 P.M., in Room 237, Technical High School, 43rd and Broadway, Oakland, Calif. The entire course of 15 lectures will be given to A. W. S. members at $5.00 and to non-members at $10.00.

## SOUTH TEXAS

A very interesting and educational talk was made by Mr. Charles Lewis of Cook Heat Treating Company on the Metallurgy of Welding, at the September 13th meeting of the South Texas Section. Mr. Lewis' talk was followed by a very lively and interesting discussion in which many questions were asked.

## TULSA

Dr. V. N. Krivobok of the Allegheny Ludlum Steel Corporation was the guest speaker at the October 4th meeting of the Tulsa Section held at the Mayo Hotel. The subject of Dr. Krivobok's lecture was "Characteristics and Properties of Welded Stainless Steels," which was illustrated with motion pictures and slides.

## WASHINGTON, D. C.

At its meeting on Oct. 3rd Mr. David Arnott, Vice-President and Chief Engineer of the American Bureau of Shipping, had been scheduled to talk on the subject of "Welded Ship Construction from the Viewpoint of the American Bureau of Shipping." However, Mr. Arnott was unable to attend and sent his assistant, Mr. Lyell Wilson, in his place. The Section felt especially fortunate in having Mr. Wilson because he has had many years' experience in the American Bureau of Shipping and is a recognized authority on the construction of maritime vessels.

The subject was introduced by describing the limitations of wooden ships, of which the joints were the most vulnerable parts. With the advent of wrought-iron plates, which were of necessity available only in small sizes, the problem of fastenings was somewhat simplified by riveting. About the beginning of the century, Bessemer steel, and later open-hearth steel, replaced wrought iron and made available much larger structural plates. Riveted joints were fewer in number, and the weight of the structure consequently decreased. Refinements in riveted design and knowledge of stress distribution in riveted joints reached a peak about twenty years ago, while at the same time welding was given a great impetus with the development of the coated electrode, and the American Bureau of Shipping announced that they would give consideration to an all-welded vessel, much to the consternation of foreign underwriters and shipbuilders.

Mr. Wilson showed a chart illustrating the decline of riveting and the rise of welding in the years up to and including 1938. This showed the rise to the present condition of welding being used in all but about $16^{2}/_{3}\%$ of the joints in shipbuilding. This should be qualified by the fact that shell seams are still two-thirds riveted.

In conclusion, Mr. Wilson presented the Washington Section with an attractive and interesting volume entitled, *American Bureau of Shipping—Seventy-Fifth Anniversary—1862–1937*, which will no doubt be found extremely valuable to the shipbuilders of this group.

The great interest shown in discussion of the speaker's paper caused the group to be held until after ten o'clock and, though considerably extended, it was agreed by everyone that the Section had had an instructive and entertaining technical meeting.

## WICHITA

The speaker for the October meeting was Dr. V. N. Krivobok of the Allegheny Ludlum Steel Corp., whose subject was "Characteristics and Properties of Welded Stainless Steel," which was well received by the members in attendance. The aircraft and refineries were well represented at this meeting.

The following is the program for the remainder of the 1940–41 season:

Nov. 13th—"Welding Profits Versus Prejudice," by J. F. Lincoln, Pres., Lincoln Electric Co.

Dec. 4th—"Construction and Fabrication Dealing Especially with Welded Design," by A. S. Low, Austin Company.

Jan. 15th—"New Developments in Connection with the Use of Oxy-Acetylene Welding," by F. C. Hutchison, Mgr., Process Service, The Linde Air Products Co.

Feb. 5th—"Heat and Mechanical Stress in Welding," by W. G. Theisinger, Lukens Steel Co. The forming of heads for pressure vessels, slides and moving pictures.

March 5th—"Spot and Resistance Welding," by J. D. Gordon, Gen. Mgr., Taylor Winfield Corp.

April 9th—"Procedure Control of Welding," by O. T. Barnett, Black, Sivalls & Bryson, Inc.

May 7th—Annual Election of Officers. "Hard Facing," by R. L. Lerch, Haynes Stellite Co.

## YORK-CENTRAL PENNSYLVANIA

The York-Central Pennsylvania Section held their first regular monthly meeting of the 1940–41 season on Monday evening, September 23rd. About 80 members and guests were present to hear Mr. Edward J. Brady talk on "Arc Welding the Stainless Steels." Mr. Brady is Vice-President and General Manager of Alloy Rods Corp., York, Pa. His talk covered the entire range of stainless analysis from the 4–6% chromium steels to the high alloy nickel chromium steels. Mr. Brady showed the necessity of having a metallurgical knowledge of the base metal to insure correct welding procedure. It was a very interesting presentation of this subject and a very lively discussion followed the lecture.

## YOUNGSTOWN

The first meeting of the Youngstown Section of the season was held at the Ohio Hotel, October 15th, and the following officers and committees were elected for the coming year:

*Chairman*—J. D. Gordon, Taylor Winfield Corp.

*Vice-Chairman*—W. Tam, Chicago Bridge & Iron Co.

*Secretary-Treasurer*—A. L. Williams, Federal Machine & Welder Co.

*Speakers Committee*—A. O. Miller, Petroleum Iron Works; C. R. Riggle, Ohio Edison Co.

*Entertainment Committee*—T. E. Jones, Federal Machine & Welder Co.; T. W. Long, Taylor-Winfield Corp.

*Subjects for Discussion Committee*—N. T. Lamond, United Eng. & Fdry. Co.; J. H. Cooper, Taylor-Winfield Corp.

*Membership Committee*—Paul Maloney, Linde Air Products Co.; Robert Haas, Lincoln Electric Co.

*Coordination Committee*—Benjamin L. Wise, Federal Machine & Welder Co.; Thomas Backus, Jr., Carnegie-Illinois Steel Corp.

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## OLD STACK SAVED

Believed to be the first of its kind ever attempted, an ingenious electric welding job has saved a large public utility company from a possible plant shutdown with its accompanying financial loss, plus the additional cost of entirely new boiler stacks. Even neglecting a plant shutdown which would have been ruinous, a 200-ampere welder repaired for less than 1/3 the estimated cost of new stacks, the two badly corroded 75-foot steel stacks.

Engineers upon inspecting two of the company's three 20-year-old steel stacks found that the 3/8-inch thick steel center plates had been corroded down to as little as 1/64 inch; in some places found a full 1/4 inch of rust. The cause was the corrosive action of combustion products from the forced-draft coal-fired boilers. In an effort to forestall a possible shutdown, the company called in the Weldrite Corporation and asked them to repair the stacks, if possible.

To solve the problem of supporting the top half of the stack so that the corroded plates could be removed, offset steel angles were welded across the faulty section. The old plates were cut out, leaving the stack's upper portion supported only by the angles. It is believed this is the first time such a method of support has every been employed for a welding job of this kind.

Up now came the welders with new steel plates. Working swiftly, they welded in place on each stack eight 9 ft. x 4 ft. x 3/8-in. new plates. Three-inch vertical overlaps were employed at the junctures of the old and new steel.

During the time the center section plates were out, the boilers were shut down, but before completion of the welding they had been re-fired. Had a new brick chimney been built, or new steel stacks provided, the boilers would necessarily have had to shut down completely while breeching was being installed or stacks were erected. Cost of repairing the two steel stacks by welding was done at less than 1/5 the estimated cost of a new brick structure, taking no account of the expense of the shutdown which would have been necessary.

*Photo Courtesy Westinghouse Elec. & Mfg. Co.*

**Welding New Center Section Plates on This 75-Foot Boiler Stack Saved a Large Public Utility from Building a New Structure with Consequent Long, Costly Boiler Shutdown. A 200-Amp. Welder, and 200 Pounds of 5/32-Inch Electrodes Were Used on This Ingenious Job, Enabling a Considerable Monetary Construction and Operating Saving to Be Made**

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## EYE ACCIDENTS

To help decrease industrial eye accidents which annually cost $50,000,000 according to Louis Resnick of the National Society for the Prevention of Blindness, the American Optical Company, Southbridge, Mass., has just published an interesting and dramatic illustrated talk on the cost and causes of eye accidents with suggestions included to eliminate the causes and lower the costs.

The talk is supported by a series of significant charts and has been prepared for delivery before safety engineers, management executives and people or organizations interested in the safety movement. Copies of the talk can be borrowed from the optical concern which will be glad to supply a speaker to present it, if one is desired. Easily delivered in thirty minutes or less, the talk is free of advertising material.

The theme of the message is—Eyes Are Expensive Targets—and the point is amply proved by factual matter and statistics included in the talk and charts.

This illustrated talk, so far as known, is the first of its kind to be prepared by any manufacturer of safety equipment.

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## REINFORCING SUBWAY TUNNELS

Tunnel beams to be used in the construction of the new Chicago Subway, are being arc welded in the shop of the Mississippi Valley Structural Steel Company, Melrose Park, Ill. Assembly line operations are being used successfully in fabrication. After being bent and sawed, the steel H beams are carried on rollers to this operator who welds end-plates to them with the aid of a 300-ampere d.-c. arc welder and shielded electrodes. These end-plates are used in bolting the separate beams together in tunnel construction.

*Photo Courtesy General Electric Company*

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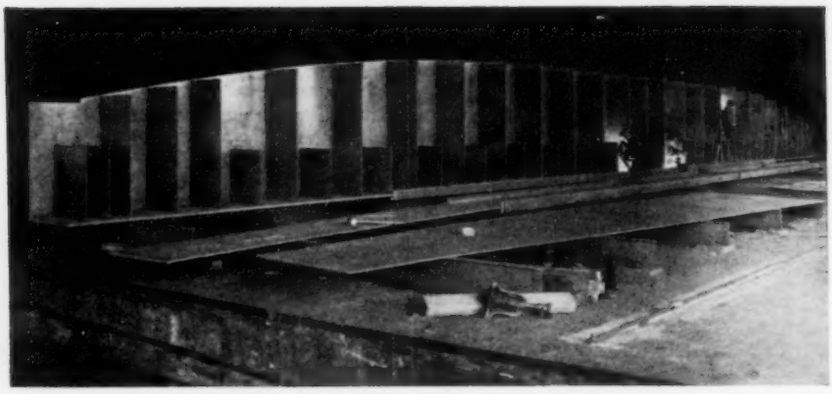
## ALL-WELDED GIRDER

The accompanying photograph shows under construction a giant all-welded girder for a Cleveland overhead traveling crane at The Cleveland Crane & Engineering Company, Wickliffe, Ohio. When completed this will be the world's largest all-welded crane girder.



All-Welded Girder

Plates ranging in thickness from $^{7}/_{16}$ inch to $1^{1}/_{4}$ inches are being welded into position. This girder when completed will weigh 45 tons, have a span of 105 ft. 0 in. and be over 8 ft. 0 in. high at middle.

The girder will be stronger and more rigid for its weight than possible by any other method of construction.

The reinforcing diaphragms are welded not only to the web plates, but also to the top plate—an advantage exclusive with the welded construction. The diaphragms are spaced so close that they alone will support the trolley rails without depending on the top plate, thus eliminating possibility of plate cracking.

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## TECHNICAL DICTIONARY

Chambers's Technical Dictionary, compiled by a staff of thirty experts under the editorship of C. F. Tweney, Editor of "A Technological and Scientific Dictionary," and L. E. C. Hughes, of the Imperial College of Science and Technology, London. Price, $5.00.

This new and authoritative work of reference contains many thousands of terms drawn from about a hundred branches of scientific and technological activity.

Its aim is to give, in the light of current knowledge, definitions of terms that are of fundamental significance in pure and applied science, in all branches of engineering and construction, including aeronautics, and in the larger manufacturing industries and skilled trades.

It is a dictionary written by specialists for interested workers of all kinds, manufacturers, scientists, technicians, editors, teachers, students and general readers.

All definitions are the work of experts; many of them are here formulated for the first time, and a great many more have never previously appeared in a work of handy dimensions.

The following are some of the main fields covered by the Dictionary:

Acoustics and Sound Recording, Aeronautics, Astronomy, Botany, Building and Construction;

Electric Communications (Telegraphy and Telephony), Engineering (Mechanical, Electrical, Civil, Marine, Hydraulic, Sanitary), Geology and Mineralogy, Horology;

Illumination, Medicine, Surgery, and Veterinary Science, Metallurgy, Meteorology, Mining;

Photography and Cinematography, Physics and Chemistry, Printing and Typography, Radio and Television, Textiles and Allied Trades, Zoology.

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## RESISTANCE WELDING ELECTRODES AND DIES

The Electroloy Company, Inc., of 1600 Seaview Ave., Bridgeport, Conn., has just issued an exceedingly interesting catalog of Electroloy Alloys for Resistance Welding Electrodes and Dies. Full information is given of the typical physical properties necessary to manufacturers and users of welding equipment for spot welding, seam welding, flash butt and projection welding.

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## THE WELDING OF CAST IRON BY THE OXY-ACETYLENE PROCESS

**L. Tibbenham, M.I.Mech.E.**

This book deals in a practical way with every detail of the process of the oxy-acetylene welding of cast iron. Such subjects as gases employed, varieties of generator plants, composition of welding rods and fluxes, vital facts in the metallurgy of cast iron relating to welding, and methods of preheating are competently dealt with. The new process of low-temperature welding of cast iron is fully explained, as well as bronze welding and its many uses. The book contains many photographs and working diagrams.

The book of 88 pages is published by Sir Isaac Pitman of London and New York. Price $1.50.

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## WATERSPHERE

The illustration shows a 50,000-gallon watersphere at Waynedale, a suburb of Fort Wayne, Indiana.

These structures are unique in that there are no structural members, that is, no angles, channels, I beams, H beams or T's used in construction. Furthermore, the riser pipe is the sole support of the tank and serves as the inlet and outlet.

Here are some interesting dimensions in connection with the sphere.

Overall height—101 ft. 6 in.

Diameter of sphere—24 ft.

Height to top of riser—76 ft.

Riser diameter at junction with tank—4 ft.

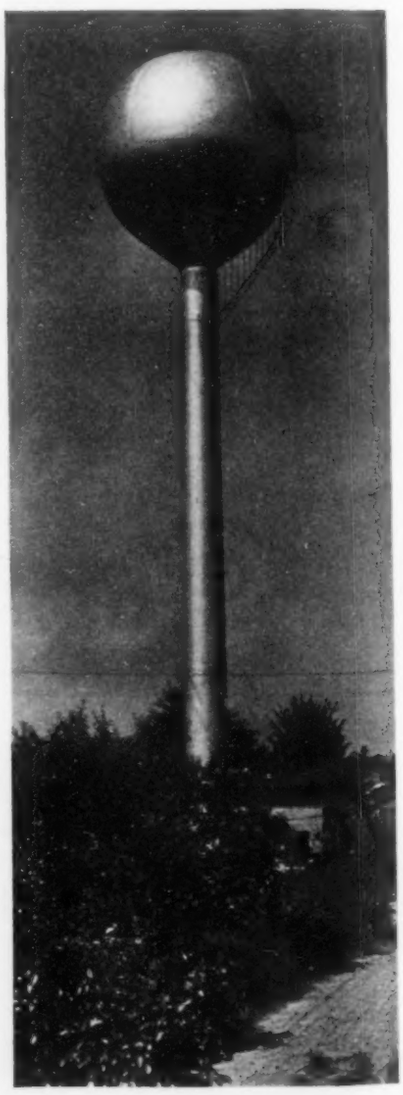
Riser diameter at junction with base frustum—16 ft.

Plates of sphere—$^{1}/_{4}$ in.

Frustum plates—$^{3}/_{4}$ in.

Plates of the supporting riser vary from $^{1}/_{2}$ in. at the bottom to $^{3}/_{8}$ in. at the top.

A horizontal pull of 9000 lb at the top of the riser where it has its smallest diameter of 4 ft resulted in a horizontal deflection of $1^{5}/_{8}$ in.



# PRESIDENT'S REPORT TO THE MEMBERS OF THE AMERICAN WELDING SOCIETY

**For the Administrative Year Ending September 30, 1940**

By George T. Horton

During the administrative year just ended the Society has broken all records in membership growth, financial stability, Welding Journal volume, advertising income, number of technical reports completed, Annual Meeting attendance, and the volume of research work conducted. Of equal importance is the establishment of a closer relationship and cooperation with the local Sections, the broadening of the base of support for the research program, and new affiliations with other technical societies and trade associations in technical and research work. Brief summaries of the major activities are furnished in the Report handed to you today.

Twenty-one years ago the American Welding Society was founded to provide united and cooperative action in advancing the knowledge and art of welding. From very modest beginnings indeed, the infant has grown to a stature which, at maturity, takes its place on equal footing with the other large important engineering and scientific bodies. Its membership of nearly forty-five hundred scattered throughout the civilized world, with more than forty important local Sections in the principal industrial centers of the United States, is an indication of its size.

More important than these visible manifestations of growth and well-being is the maintenance of the high ideals set for it by its far-sighted founders.

It has passed through many years of trying times brought about by general economic conditions and internally by honest differences of opinion.

In accomplishments the American Welding Society outranks all others. Its codes are adopted widely by legislative bodies and by other technical and scientific organizations. Its basic standards such as Definitions, Filler Metal Specifications, Qualification of Welding Operators, Symbols, form part of all application codes relating to welding. In the amount of cooperative research work carried out it stands unique among all other engineering and scientific bodies. Its publications, The Welding Journal and Handbook, are recognized as authoritative.

All of these things are made possible through the cooperative action of many. The Society enjoys the whole-hearted support of manufacturers, fabricators and users, as well as governmental departments. Service on its numerous committees, national and local, are accepted as an honor and an opportunity to do service for a common good.

As I retire as President of the Society, I wish everyone to know how much I have appreciated the honor of holding the office. No one realizes better than I how little I have contributed to all the good things just enumerated and how much the Society is indebted to the other officers, members of the Board and the staff, to say nothing of our good friends who have seen fit to advertise or exhibit with us and whose support has meant so much, and even so, the Society is a loser inasmuch as death has just recently claimed Mr. Charles A. McCune, our staunchest friend and most capable supporter.

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*There follows a brief account of some of the important activities of the Society, Board of Directors and its numerous committees.*

## Summary of Activities American Welding Society

*Meetings of the Board of Directors*

Three meetings of the Board have been held during the past year, one in Chicago last October and the other two in New York. These latter have been held jointly with the Executive Committee of the Society. In addition, the Executive Committee held four meetings in New York.

*By-Law Amendments*

By a recently adopted amendment to the By-Laws September 1st has been established as a single expiration date for membership dues. The purpose of this amendment is to reduce clerical work of the Sections and Headquarters, and to assist companies which are paying membership dues of a large number of their employees. The putting of this By-Law into effect necessitated a change in the payment to the Sections. Heretofore $100 has been paid to the Sections each year on the anniversary date of their organization. Hereafter this payment will be made at the beginning of each fiscal year when the Society is in funds to meet this large payment.

*Increase in Return to Sections on Membership Dues* has also been effected by an amendment to the By-Laws. The primary purpose of this is to build up the Society prestige through good technical programs and educational activities.

The changeover to the single expiration date for dues and increase in returns to Sections has entailed considerable work on the part of the staff but it is expected with the changeover, billing and the keeping of books and records, as well as reporting, will be materially reduced, both at Headquarters and the Sections.

*Permanent Funds Committee.*—Of special interest among the By-Law Amendments recently adopted is that providing for the appointment of a Permanent Funds Committee. This Committee will handle the reserve funds of the Society set aside upon authorization of the Board of Directors.

*Finances*

You will be glad to learn the Society is in a condition of financial stability. Though the year end statement is not yet available, the last Accountant's Report for the eleven (11) month period ended August 31, 1940, indicated a net increase of income over expense in the amount of $8731.98.

At the beginning of this year, 1% of the gross income for the fiscal year ended September 30, 1939, was added to the reserve fund accumulated through the efforts of the first Welding Handbook Committee. Provision for a similar addition to the Reserve fund was made in the budget for the year just ended. The sale of the first Welding Handbook shows a net addition to this account.

It is to be noted with satisfaction that our annual income from membership dues and Journal advertising during the past year has exceeded that contemplated by the budget and is largely responsible for our net gain. We are grateful to all responsible for this achievement.

Our sale of the Metallurgical Pamphlet and other bulletins has also added to the funds.

A detailed financial report for the year ending September 30, 1940, will be published in the Society Yearbook.

*Membership*

The Membership Committee has been active, and the value of its work has been attested by the continuous membership growth. The Committee has been concerned not only with the acquisition of new members but also in retaining the interest of its present members. Where it has been found that members cannot meet the dues in one payment, instalment payment has been permitted with very favorable results. The personnel of the Committee is composed of Section representatives;

to expand the membership activities in the Section, the Chairmen of the Sections have been added to the personnel of the Membership Committee and have been furnished with all data sent to that Committee.

The solicitation of potential members registered at the last Annual Meeting brought in many new members. The Section Membership Committees have been urged to capitalize on the increased importance of welding in the metal industry by educating those in their localities that should be members on the benefits to be gained through membership in the AMERICAN WELDING SOCIETY, and by stressing the timeliness of their joining now.

There are indications that plans are now under way for membership campaigns.

Membership statement for the twelve months ending September 30, 1940, shows a total membership of 4344 and that the largest gain has been in the Member and Associate Member grades. It is believed that the large number of Operating Members acquired during the year is due probably to the desire for welding knowledge on the part of trade school students.

*Delinquents.*—Although the total number of delinquencies has increased slightly this year, we are pleased that we have been able to reduce delinquencies in the Sustaining and Member grades, thus reducing the amount of outstanding dues.

The inclusion of a friendly printed notice in the last issue of the Journal being sent to delinquent members reminding them that further copies of the Journal will not be received until dues are paid, has proved an excellent means of effecting payment.

Report of Membership Committee and statement showing net changes during the year will be published in the Yearbook.

*Ways and Means Committee*

Limited success in the operation of local subcommittees in Sections of the Society has led the Ways and Means Committee to abandon this plan of approach and to concentrate activities in direct approach to specific industries. Groups approached or under consideration are Automotive, Resistance Welding, Shipbuilding, Pipe and Machinery Manufacturers.

*Sections*

Our Sections continue to be a most important factor in the advancement of welding. With a few exceptions all have had a successful year. The technical programs have been well planned and given sufficient publicity to bring out good-sized audiences.

The lecture courses conducted by the Sections have attracted wide attention this year. The Washington Section course had the largest enrolment—1000—made up largely of engineers in Government service. The average attendance at the eight lectures was 500. The course commenced in January and ended in April.

The New York Section course on Welding Metallurgy was also enthusiastically received and was repeated in other centers. The paid enrolment was 256. This series of lectures was printed in pamphlet form and made available to the Sections and to the membership.

The Los Angeles Section course on Fundamentals of Welding had a paid enrolment of 154. Here again the series was made available in pamphlet form but unfortunately the number of surplus copies was limited.

Cleveland ran two series of lectures, one for the professional men and the other for the practical men. The lecture courses sponsored by the St. Louis, Tulsa, Northwest, Oklahoma City and Northern New York Sections created considerable interest in welding.

In addition to the Tri-State Welding Conference covered in another part of this report, the Cleveland Section sponsored a Welding Conference. This Conference was such an outstanding success it is planned to repeat it next year. Registration was over 450. A short Conference in Welding Engineering was sponsored by the Columbus Section.

Inspection trips and social activities of the Sections during the past year have done much to stimulate good fellowship and interest in the Society generally.

A number of the Sections, particularly those in the Middle West and West, have been most responsive to the suggestion of Headquarters that speakers for Section meetings be secured to address a group of adjacent Sections in sequence. Meetings of Section Chairmen and Section Program Committee Chairmen were held during the summer to plan the season's programs for the group, the Sections to contact the speakers decided upon, chosen from lists supplied by Headquarters. It is hoped that the success of the plan in the groups which have adopted it will result in its widespread adoption next year.

*New Sections Organized*

During the 1939–40 season, three new Sections have been organized: the Lake Shore, with headquarters at Manitowoc, Wisconsin; the Northern New Jersey, with headquarters at Newark, New Jersey; and the Canal Zone just recently organized.

Unfortunately, because of the completion of the Government project at Fort Peck, Montana, welding interest there waned to the extent that it has been necessary to disband the Section. Due to inactivity at the present time, it has been found necessary also to disband the Section in Memphis, though there is hope of reviving interest there at some future date.

Consideration is being given to inactivity in several of the other Sections but it is too soon to predict the outcome of our investigations.

Complying with a request of the Sections, the Board of Directors authorized the National By-Laws Committee to prepare an addition to Article III, Section 2 of the Section By-Laws providing for Section Affiliates. The amount of dues of this classification has been limited to not more than $5.00. Section Affiliates are entitled to participate in meetings and other educational activities but do not have the privilege of membership in the National Society.

*President's and Technical Secretary's Visits*

President Horton and Technical Secretary Spraragen attended the Tri-State Welding Conference in Pittsburgh, April 26th. This Conference is held annually and is sponsored jointly by the A. W. S. Pittsburgh Section and the Engineering Societies of Western Pennsylvania. It included a very interesting visit to the Dravo Corporation plant followed by luncheon attended by 150 members and guests. The afternoon session devoted to the presentation of technical papers was attended by over 300, and the evening session by over 150 members and guests. A get-together dinner was held between these sessions which President Horton attended.

President Horton also attended President's Nights arranged by the Washington and Milwaukee Sections. This is the second of these nights held by the Washington Section, and because of the reputation gained on the first occasion it drew a large and representative audience. Guests of the evening included a number of the National Past-Presidents, Vice-Presidents and the National Secretary.

President Horton visited with the Oklahoma City Section on March 1st and the Tulsa Section on March 2nd, the Northwest Section in Minneapolis on September 10th and the Peoria Section on October 2nd, where he presented slides of welded structures. He also was the official representative of the Society at the Annual Convention of the International Acetylene Association in Milwaukee.

To comply with requests coming from Sections in the West and Southwest that a representative of Headquarters make regular visits to the Sections, the Technical Secretary was authorized to arrange a tour in the early spring. His trip included visits to Chicago, Milwaukee (where he also attended the I. A. A. Convention), Moline, Illinois (Quad-Cities Section), Kansas City, Wichita and Oklahoma City. In some cases he conferred with key men of the Section, and in others addressed the Section membership. He was enthusiastically received and it was felt that the trip was profitable from the angle that it established necessary personal contacts.

This year many of the Sections have had the pleasure of visits from the Vice-Presidents of the Society.

*Annual Meeting*

The 1939 Annual Meeting was the best meeting held to date from the standpoint of Technical Sessions, Exhibits and Attendance. Over 1400 attended the technical sessions of the A. W. S.; 250, the President's Reception Sunday afternoon; 1100, the Stag on Wednesday evening, and 500, the Annual Dinner. Thirty-five welding exhibitors participated in the National Metals Exposition.

In order to tie in more closely the activities of the local committees in charge of local arrangements with those of the National Committee, it has been arranged so that the Chairman of the local Section where the meeting is to be held will serve as Vice-Chairman.

The Manufacturers Committee met last October in Chicago for the purpose of discussing future exhibits, method of handling exhibits, cooperation with the American Society of Metals, and other matters of interest. As a result of this meeting

the Manufacturers Committee recommended to the Board of Directors that A. S. M. invitation to the A. W. S. to participate in the 1940 National Metals Exposition be accepted. Also the Manufacturers Committee asked that the A. W. S. Board of Directors request the National Metal Exposition and Congress to give consideration to a biannual Exposition. (The Board complied with this request.) The Manufacturers Committee has assisted the Director of the National Metal Exposition in securing the maximum number of welding exhibitors for the 1940 Exposition. There is every indication that this Show will surpass that of 1939.

*Technical Program*

Some 53 papers are scheduled for presentation at the forthcoming meeting of the Society.

During the year, the Meetings and Papers Committee sent out a questionnaire to the entire membership soliciting opinions of the membership in regard to the type of papers which should be published. The results of this questionnaire serve as a guide to both the Subcommittee on Publications and the Subcommittee on Program.

*Welding Journal*

All-time highs were reached by THE WELDING JOURNAL during the fiscal year ended September 30th in the amount of advertising and in the number of pages published by THE WELDING JOURNAL. Correspondingly, the forthcoming meeting of the Society in Cleveland will be the greatest in the history, both from the total number of papers to be presented, their diversity and importance.

For the year ending September 30th, the Society published 1000 pages in the regular portion of the Journal and 472 pages in the Welding Research Supplement.

The Meetings and Papers Committee wishes to report that the major activities of the Committee are due largely to the work of the Subcommittees on Publications and Program. These two Subcommittees have handled in an efficient manner the publication of THE WELDING JOURNAL, the arrangements for technical programs of Annual Meetings and, occasionally, assistance to Sections in their meetings.

*Publicity*

This past year the Publicity Committee concentrated its efforts on Annual Meeting publicity. A program of activity was laid out well in advance and the members of the Committee were informed of their assignments. These included the preparation and distribution of 40,000 stickers, 5000 posters and programs, and the abstracts of the Technical Session papers to the trade journals and newspapers.

The local group looked after the distribution of this publicity material in local areas. It also assumed responsibility for getting news stories on the technical sessions to the local newspapers on the morning previous to the day on which the sessions took place.

Special news stories in connection with the Exposition, social affairs, prominent speakers, medal awards and the like were prepared for trade journals and local newspapers.

In order to avoid duplication of effort in connection with the Annual Meeting publicity, the A. W. S. Publicity Committee cooperated with the Publicity Committees on the A. S. M. and the other technical societies participating in the National Metals Congress.

The Committee held several meetings prior to the opening of the Convention and arranged so that one member was on hand in the Press Room at the Stevens Hotel throughout the Convention to meet representatives of the local press and trade papers. The same procedure is being followed in connection with the 1940 Convention.

*Welding Research Committee*

Outstanding in the accomplishments of the Welding Research Committee is the broadening of the base of support for the work of the Committee. Last year the number of subscribing organizations and companies was thirty-eight; this year the number has been increased to fifty-eight, which represents more than a 52% increase in a single year. The work of the Literature Division continues to receive worldwide appreciation. During the year 10 critical digests were published, and five made available in mimeograph form. The Fundamental Research Division has increased its usefulness and its productivity. To a considerable extent this has been possible through the availability of increased appropriations by the Main Committee for the work of the Fundamental Research Division. In the Industrial field most of the committees are making creditable progress, but the financing of the Carbon-Manganese (Weldability) and Structural Steel projects deserve special mention.

Better relationships exist between the Committee and affiliated trade associations and societies. For example, the American Iron and Steel Institute has trebled its support to the work of the Committee. Among the national associations that have become affiliated with the work of the Committee and who are now supporting its activities are: American Society of Civil Engineers, American Society for Metals, American Society for Testing Materials.

At this time we believe it is important and significant to indicate that through the past several years the Welding Research Committee has built an organization which embraces the leading scientific welding research talent of this country as represented by the best experts and technicians available in industry, governmental departments, university laboratories and scientific organizations. If the Committee were to be called upon in connection with the national defense measures, it could muster with efficiency, and without loss of time, the major available scientific and engineering resources in the welding field for such work. This machine represents a well-knit, smoothly working organization with important contacts here and abroad. It already has made available in condensed usable form the major portion of welding research information existing in the literature of the world to 1936. The literature on specific subjects for the past four years could be quickly reviewed and made available in an emergency. It has trained personnel in the leading universities and governmental laboratories to undertake specific problems. Key experts are already serving on important committees.

The result of this cooperative research program in the field of welding is a reduction in the over-all cost to industry, its customers and the nation, a higher quality of production, a higher industrial efficiency, a sounder and more rapid development and a much more rapid education of the university research workers and industrial engineers involved, since they are intimately associated with the best scientific welding research minds available in the country.

### Technical Activities

The year 1939–40 has been an outstanding one from the point of view of technical accomplishments. Nine Committees have completed the preparation of codes or reports of which five were published and four awaiting publication. Four additional codes and reports are nearing completion.

The organization of four new Committees was completed; five were reorganized, and one Committee was discharged. The new Committees added during the year are:

- Committee on Non-Destructive Tests for Welds.
- Committee on Code for Fusion Welding High Alloy Steel Engineering Structures.
- Committee on Inspection of Welding.
- A. S. A. Sectional Committee C52—Electric Welding Apparatus.

The Committees that have been reorganized are:

- Committee on Building Codes.
- Committee on Standard Tests for Welds.
- Committee on Grouping of Materials According to Weldability.
- Committee on Minimum Requirements of Instructions for Welding Operators in Trade Schools.
- A. W. S.-A. S. M. E. Conference Committee.

The Society has also appointed representatives on the following:

- A. S. A. Standardization Project "Preferred Voltages—100 Volts and Under."
- A. S. T. M. Committee A10—Subcommittee VII on Welding.
- American Coordinating Committee on Corrosion.

The following Codes were completed during the year of which the first five were published, and the remaining awaiting publication:

- Tentative Standard Methods for Mechanical Testing of Welds.
- Tentative Definitions of Welding Terms and Master Chart of Welding Processes.
- Tentative Rules for Field Welding of Storage Tanks.
- Tentative Specifications for Iron and Steel Arc Welding Electrodes.

Welding Symbols and Instructions for Their Use.

Recommended Procedure to Be Followed in Preparing for Welding or Cutting Certain Types of Containers Which Have Held Combustibles.

A. W. W. A.-A. W. S. Tentative Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs.

Standard Qualification Procedure—Section I—Manual Arc and Gas Welding of Ferrous Materials.

Welding of Pipe Joints (Chapter 4 of A. S. A. Code for Pressure Piping).

The following Codes and reports are nearing completion:

Specifications for Welded Highway and Railway Bridges.

Grouping of Materials According to Weldability.

Report on Thermal Stresses and Shrinkage in Welded Ship Construction.

Welding Symbols and Instructions for Their Use (1940 revision).

During the year the Committee on Outline of Work proposed new Rules to Govern Organization, Functions and Operations of Technical Committees, which were adopted by the Executive Committee.

The Committee instigated the preparation of records on membership experience both from the view-point of possible service on committees and as experts in specific fields.

A somewhat new departure in type of organization has been proposed in connection with the appointment of a Resistance Welding Standards Committee. This proposal contemplates the appointment of a fairly large Steering Committee with appropriate working Subcommittees. The principal advantages of the organization of this type of Committee in the resistance welding field will be to promote progress, bring about better coordination of needed work and assure acceptance of standards promulgated.

The Committee on Outline of Work has held three meetings and has made recommendations from time to time on the basis of letter ballots and correspondence.

### *Reports of Technical Committees*

#### *Conference Committee on Welded Bridges*

This Committee has been quite active during the past year revising the 1938 specifications, looking toward a new edition late this fall.

The Committee has held three meetings this year, the last meeting in July being a two-day meeting, at which time the work of revision was practically concluded, the data now being in the hands of the Editing Committee.

This was made possible by considerable work by the Subcommittees, in addition to the main Committee work. Credit should be given particularly to Subcommittees on Design and Workmanship.

#### *Committee on Building Codes*

Anticipating the first meeting of this Committee, which was held in New York on March 5, 1940, a tentative outline was prepared for the purpose of collecting all related subject matter for consideration in the drafting of the proposed code.

A careful study of these data resulted in the adoption by the Committee, at its April 9, 1940, meeting, of a skeleton form along which lines the text was to be developed.

This form, like the arrangement of the present code for Fusion Welding, contemplates a division of the subject matter into two parts. The first part, covering the mandatory provisions, is to be completely self-contained and will be suitable for insertion into the existing master building code of a municipality. The second part, containing supplementary related data, is intended to assist in the administration of the mandatory provisions so that, taken as a whole, the completed text may be adopted by citation for the regulation of welding in ordinary building construction in so far as a governing authority would be responsible for its regulation.

It was considered desirable that the completed work harmonize with the revised A. W. S. Bridge Specification as to recommended technique and parallel this specification as to arrangement and language in so far as the somewhat different functions of the two instruments would permit.

The efforts of the Committee have been directed principally at the mandatory provisions, this portion being not only the more important, but, by far, the greater part of the task. These provisions logically divide into five sections for which Subcommittees have been assigned to draft the text.

Tentative drafts have been prepared for all of these sections and the Subcommittee responsible for one section has reconciled the sundry suggestions developed, and submitted a report which is now awaiting the progress of the other Subcommittees for consideration by the whole Committee.

#### *Committee on Standard Qualification Procedure*

During the past year the Committee has been engaged in making final revisions to the Standard Qualification Procedure and copy of the final draft is now in the Society's hands.

The section of the Qualification Procedure reported upon applies only to the manual arc- and gas-welding processes for those welding ferrous metals which in their unwelded condition will withstand bending in the guided bend tester. The Committee intends to give consideration to suitable methods of qualification for conditions not covered by the above.

The Standard Qualification Procedure has been made a part of the 1940 revision of the A. S. M. E. Boiler Code and the Unfired Pressure Vessel Code and has also been incorporated in the revision now being made of the A. S. A. Code for Pressure Piping.

#### *Committee on Pressure Piping*

The membership of this Committee is identical with that of the A. S. A. Sectional Committee on Code for Pressure Piping, Subcommittee No. 8, Sub-Group No. 4.

During the past year the Committee has completed a revision of Chapter 4 on the welding of pipe joints for the A. S. A. Pressure Piping Code, which revision has been accepted by the Main Committee.

#### *Committee on Filler Metal Specifications*

The Committee has, in the past year, brought the Specifications for Iron and Steel Arc-Welding Electrodes to completion and has obtained the acceptance of the A. S. T. M. of this specification. The specification is now in printed form, sponsored by both societies and is tentative for at least one year.

Subcommittees on the following subjects and with the following Chairmen have been appointed: Mr. J. H. Critchett, Gas Welding Rods; Mr. R. D. Thomas, High Alloy Steels; Mr. G. O. Hoglund, Aluminum and Aluminum Alloys; Mr. O. B. J. Fraser, Nickel & Nickel Alloys.

#### *Committee on Welded Elevated Water Tanks*

During the past year the Committee of the AMERICAN WELDING SOCIETY on Welded Elevated Water Tanks and Standpipes has been actively at work in conjunction with a similar committee of the American Water Works Association. Five drafts of specifications have been prepared, the fifth and final draft having been approved as a tentative specification by the American Water Works Association at its annual convention in Kansas City in April. In this specification all specifications relative to welding have been taken from the AMERICAN WELDING SOCIETY "Tentative Rules for Field Welding of Storage Tanks."

The specifications are now in process of editing and printing by the American Water Works Association.

#### *Committee on Rules for Field Welding of Storage Tanks*

This Committee was authorized on June 5, 1940. The Committee held three meetings and conducted voluminous correspondence.

Six editions of the specifications were prepared and submitted to the Committee members for discussion. Copies of one of the late drafts were submitted to the members of the A. P. I. Tank Committee for comments. The rules were approved by a unanimous letter ballot received from each of the members of the Committee. The rules were adopted by the Executive Committee on April 4, 1940, that is, ten months after the Committee was authorized. The rules have been published by the Society and are now in use.

#### *A. P. I.–A. W. S. Conference Committee on Welded Oil Storage Tanks*

Two meetings were held during the past year, one in Chicago on November 12th at the A. P. I. Mid-Year Convention and the other at Forth Worth, Texas, on May 26th at the annual A. P. I. Convention. Through the cooperation of this Committee, the A. P. I. Tank Committee has adopted the following A. W. S. Codes —"Nomenclature," "Symbols," "Electrodes" and "Standard Qualification Procedure." They have also adopted many other items from the A. W. S. "Tentative Rules for Field Welding of Storage Tanks."

There is now very substantial agreement between the A. P. I. Welded Tank

Code and the A. W. S. "Tentative Rules for Field Welding of Storage Tanks."

*Committee on Grouping of Materials According to Weldability*

Preliminary committee work was carried out by correspondence and a tentative grouping of materials was prepared early in December 1939. The comments received from the Committee members on this tentative grouping resulted in a revised grouping prepared in April 1940.

A committee meeting was held in Washington, D. C., in June 1940 to discuss the second grouping of metals. As a result of this meeting a second revision on the grouping of materials was prepared. This grouping has been submitted to the Committee members for approval, following which a final report will be presented to the AMERICAN WELDING SOCIETY.

*Committee on Safety Recommendations*

During the year a Subcommittee was appointed to prepare a redraft of the AMERICAN WELDING SOCIETY'S "Tentative Recommendations Describing Procedure to Be Followed in Preparing for Welding or Cutting Certain Types of Containers Which Have Held Combustibles." The Subcommittee has now completed its work and its report has been approved by the members of the Safety Committee. It is recommended that these rules be adopted by the Directors and published.

During the year certain letters have been referred to the Chairman of the Safety Committee in the matter of health hazards. These have been answered by letter. Doubtless in the year ahead of us, several states will form committees dealing with health hazards in industry and welding will no doubt receive careful consideration. Your Chairman is keeping in touch with this situation and will see that the AMERICAN WELDING SOCIETY has proper representation on the various committees.

*A. W. S.–A. S. M. E. Conference Committee*

During the past year this Committee has been entirely revamped and the plan of cooperation with the Boiler Code Committee considerably revised. The original plan of cooperation has been to assign to our Committee detailed problems in connection with fusion welding applications to boilers and pressure vessels, but as the art has progressed, the necessity for this has been less and less in evidence. During the past few years it has been shown that the welding and metallurgical engineers in the boiler and pressure vessel plants have been better able to make recommendations concerning practices and procedures than anyone else who might be selected from the Society membership.

Accordingly it was recommended that our Committee be recast and its plan of activity so modified that it can be assigned to the development of important new welding applications in the boiler and pressure vessel field and thereby obviate the necessity of handling such development activities by the personnel of the Boiler Code Committee itself. A well-qualified Committee personnel has been selected and the first problem assigned to it was one that was fundamental in character and promises to be of vital importance. This project has to do with the recognition of copper and its alloys for the construction of welded pressure vessels, and a report on this important subject is now in preparation by the Committee.

*A. S. A. Sectional Committee C52, Electric Welding Apparatus*

The A. S. A. Sectional Committee C52, Electric Welding Apparatus has been reorganized under the sponsorship of the AMERICAN WELDING SOCIETY for the purpose of revising and bringing up to date the present standards for Electric Welding Apparatus and Resistance Welding Apparatus.

Copies of the present standards have been distributed to Committee members for study and comments and a Committee organization meeting was held on September 20th.

*Committee on Standard Tests for Welds*

The proposed Standard Methods for Mechanical Testing of Welds were on January 18, 1940, approved by the Executive Committee of the Society for publication as a tentative standard. In connection with the preparations of these methods the unnecessary deviations in methods of testing called for by the various specifications of the Society have, in general, been satisfactorily ironed out.

Following this completion of the first phase of its work, the Committee was reorganized, and the reorganized Committee is waiting for criticisms of the tentative methods before undertaking further work.

*Committee on Definitions and Chart*

The Committee's report on the revision of Tentative Definitions of Welding Terms and Master Chart of Welding Processes has been approved and published during the past year. A questionnaire has been sent to members of the technical committee to determine what additional work should be done by the Definitions Committee to make the definitions more useful to them.

*Committee on Large Welded Pipe for Hydraulic Purposes*

The second draft is now in the hands of the members of the Committee for comment and criticism.

*Committee on Non-Destructive Tests for Welds*

The appointment of this Committee was authorized by the Board of Directors in June 1939, and its personnel has only recently been completed. The date of the first meeting has been scheduled, and it is anticipated that the work of the Committee will proceed rapidly.

*Committee on Welding in Marine Construction*

The work of the Main Committee is handled through three Subcommittees as follows:

1. Subcommittee on Marine Boilers, Pressure Vessels & Piping.
2. Subcommittee on Hull Construction.
3. Subcommittee on Thermal Stresses which is actually a Subcommittee of No. 2.

The Subcommittee on Thermal Stresses held meetings at Chicago and Washington and the final report will undoubtedly be adopted at the next meeting of the Main Committee to be held sometime during the Annual Convention at Cleveland.

Following certain correspondence between Dr. Jacobus and Commander Field, Director of the Bureau of Marine Inspection and Navigation, the Chairman called a meeting of the Main Committee which was held on March 26th for the purpose of considering a tentative draft of new rules for boilers, pressure vessels and piping which was prepared by that Bureau so far as these related to welding. As a result of this meeting a number of proposals for revisions were agreed to and the recommendations of the Committee were forwarded to Commander Field in a letter from the Chairman dated March 28, 1940, which was gratefully acknowledged.

The marine industry differs from most other industries in respect that it is very closely regulated. The construction of ships and their propelling machinery is regulated by the Navy Department (Bureau of Ships) in the case of naval vessels, and by the Bureau of Marine Inspection and Navigation and the American Bureau of Shipping, or other classification society, in the case of merchant ships. However, the Committee on Welding in Marine Construction provides a useful means whereby these various administrative authorities, through their representatives on the Committee, can get together for the interchange of ideas on Welding matters. This tends toward uniformity in their various Rules and Regulations with beneficial results to the whole marine industry.

*Committee on Symbols*

At the December meeting of Subcommittee I of Sectional Committee Z32 of the American Standards Association, recommendation was made that the basic symbols published by the AMERICAN WELDING SOCIETY be approved as an American standard. There was some disagreement among the various members of the Symbols Committee of the AMERICAN WELDING SOCIETY as to the interpretation of the symbols and the instructions for their use. The disagreement has now been straightened out, and the question of adoption of the symbol system, together with all instructions, will be taken up again with the American Standards Association.

*Committee on Standards for Fusion Welding High Alloy Steel Engineering Structures*

The personnel of the Committee was appointed on June 28, 1940. Because of the great number of members on the Committee, the Chairman appointed a small Subcommittee to do the preliminary organization work. This Subcommittee, known as the Steering Committee, held a meeting in Atlantic City on June 27, 1940, to discuss the formulation of a program of work. It is anticipated that a meeting of the entire Committee will be held at some time in the near future to

consider the program outlined by the Steering Committee.

*Committee on Minimum Requirements of Instructions for Welding Operators in Trade Schools*

This newly appointed Committee held its first meeting on April 5,1940, which was preceded by a considerable amount of preliminary work achieved by discussions between the Chairman and individual Committee members. At the first meeting attention was centered on defining the scope, objectives, policies and procedures to be followed by the Committee in executing its assignment. The Committee agreed that the scope of the minimum requirements which it would formulate would include the following items:

(1) Qualifications of instructor.
(2) Manipulative content of course and average number of hours required for mastery of this content.
(3) Related instruction of course and average number of hours required for mastery of this content.
(4) Facilities and equipment of the school (minimum number of units and maximum number of student per unit at any one time).
(5) Tests (minimum tests which the student should be required to pass upon completion of the course).

The first objectives which the Committee is now working on are: (1) to accumulate information by means of a questionnaire, concerning the welding courses now being given throughout the country, and (2) to begin at once to formulate minimum requirements for instruction in the fundamental elements of welding. The Committee has been requested to complete its report as promptly as possible, as a contribution to the National Preparedness Program.

*Machinery Code Committee*

During the past year this Committee has reviewed the first draft of the new Tentative Code for Arc and Gas Welding and Gas Cutting in Machinery Construction, and has distributed a semi-final draft to all members of the Committee and other interested organizations and individuals for comment. It is anticipated that the Committee's final report will be submitted to the Society in the very near future.

## Cooperation of American Welding Society with Other Organizations

*American Institute of Electrical Engineers*

*Subcommittee on Power Supply for Welding Operations*

The Subcommittee has improved the cooperative relations between the resistance welder manufacturers, the users and the power suppliers, particularly in regard to the providing of an adequate power supply for resistance welder installations. Successful and efficient welder performance depends as much upon the adequacy of the power supply as it does upon the quality of the electrical characteristics of the welding machines themselves.

The Subcommittee has prepared a report entitled "Power Supply for Resistance Welding Machines: I. Guide to Good Electrical Performance of Resistance Welding Machines; II. Resistance Welder Installations; III. Factory Wiring for Resistance Welders," to be used as an aid in the planning of layouts for new installations and in the preparation of electrical specifications for the purchase of new equipment. The first two parts of this report have been completed and are available in reprint form and the third section is completed and should be available early in 1941.

Recommendations have also been prepared regarding National Electrical Code requirements for resistance welder installations which are being submitted to the proper Code authorities for their consideration. Purchase inquiry forms and manufacturers' data sheets have been prepared covering both mechanical data and power supply data on new installations. It is felt that the proper use of these forms will do much toward improving the relations between the manufacturers, the users and the power suppliers and will be of considerable assistance in the providing of an adequate power supply for all new installations.

*American Standards Association*

*Committee A10—Safety Code for Construction Work*

This Subcommittee practically completed its work last year and the report submitted to the American Standards Association has been accepted and will be published in the near future.

*Committee A57—Building Code Requirements for Iron and Steel*

During the year 1940, Committee A57 acted on purely structural matters, not affecting welding. It appears that in the next year or so there may arise questions directly affecting the use of welding, and for this reason it is recommended that Society representation on the above Committee be continued.

*Committee B31—Code for Pressure Piping*

Completed drafts of revisions of various sections of this Code were turned over to the Subcommittee on Plan, Scope and Editing on May 1, 1940, to be incorporated in a revised draft of the entire Code. (See A. W. S. Committee on Code for Pressure Piping report.)

*Committee C42—Definitions of Electrical Terms*

The scope of this work is as follows: "Definitions of technical terms used in electrical engineering, including correlation of definitions and terms in existing standards." This committee has, for the past ten years, been working intensively in the preparation of a glossary of electrical terms covering practically all branches of the electrical industry, the basis for which was the correlation of and additions to the definitions in standards and specifications which have been approved by the American Standards Association. It is expected that this group will adopt the A. W. S. welding definitions in so far as they are applicable.

*Committee C67—Preferred Voltages—100 Volts and Under*

The personnel of the Sectional Committee for this project is now practically complete and it is expected that the work of the Committee will get under way in the near future.

*Committee Z2—Code for Protection of Heads, Eyes and Respiratory Organs of Industrial Workers*

The work of this Committee has been completed and no meeting has been called.

*Committee Z5—Development of Ventilation Code*

A meeting of the Committee was held on October 25, 1939. It appears that that meeting was held for purposes of organization and a program of activity was outlined. However, no further meeting has been held.

*Committee Z14—Drawings and Drafting Room Practice*

*Committee Z32—Graphical Symbols and Abbreviations for Use on Drawings*

See report of A. W. S. Symbols Committee.

*Committee Z28—Work in Compressed Air*

This Committee has been inactive during the past year.

*American Society for Metals*

*Recommended Practice Committee*

Two meetings in Cleveland of the American Society for Metals Handbook Committee have been attended by the A. W. S. representative during the year. The time of issuance of the next A. S. M. Handbook has not as yet been decided upon. Active work, however, is in progress by way of assignment of members to the Subcommittees, whose duty it will be to condense and rearrange much of the material in the Handbook.

*American Society for Testing Materials*

*Committee A1—Subcommittee XXI*

Official acceptance by the A. S. T. M. Subcommittee XXI and Committee A1 of a filler metal specification for welding electrodes, which is identical with our own tentative standard, has been secured and the specification published.

*Committee B5—Copper and Copper Alloys*

Three meetings were held. Three specifications which are still under discussion have a special significance for the AMERICAN WELDING SOCIETY, thus

1. Standard Specification for Copper-base Alloys in Ingot Form for Sand Castings. Of the twenty-five alloys listed, nineteen carry from 0.75 to 25% lead which always requires special consideration in welding operations. The other six offer us less trouble.

2. Specifications B 96 and 97-36 T on Silicon Copper Alloys is under discussion. One producer wishes to add nickel to the alloy but some objection has been voiced thereto on account of the precipitation

hardening effect of silicon and nickel in a welded silicon copper alloy.

3. While it has not as yet come up for consideration by Comm. B5, Copper Plate Specification B 11–33 is up for revision at the instance of the A. S. M. E. Boiler Code Committee. This specification has not to date required that the copper be deoxidized but it is quite important that it be deoxidized since it is often welded.

*Association of American Railroads*

*Committee on Fusion Welded Tank-Car Tanks*

The Tank-Car Committee of the Association of American Railroads has not called upon the representatives of the AMERICAN WELDING SOCIETY for any work during the past year. The Committee has during the past year considered a total of 413 dockets and applications for approval of designs, materials and construction of 3829 new shipping containers and that a large percentage of these were for fusion welded containers.

The specifications for fusion welded tank car tanks considered by the Interstate Commerce Commission in 1934 have been revised and were recently resubmitted at a Public Hearing before the Interstate Commerce Commission for adoption. Pending the adoption of the specifications for fusion welded tank car tanks by the I. C. C. special authorization has been granted for the construction of 1074 tank car tanks fabricated in conformity with the proposed specifications and that reports indicate a satisfactory performance for the fusion welded tanks now in service after having transversed something over ten million miles.

*American Petroleum Institute*

*Committee on Field Welding of Casing*

At the Chicago meeting, the Chairman, Mr. Hodell, presented a written comment on revision of specifications for pipe intended for welded casing. In fields where fast running of casing is important, the use of welded casing is limited to the larger sizes. Until faster methods of welding are perfected, general use of welded casing is not anticipated, and the activity of the A. P. I. Committee on Field Welding will probably be governed by such developments.

*National Board of Boiler and Pressure Vessel Inspectors*

During the past year nine meetings have been held which were attended by our representative. These meetings have been held concurrently with meetings of the A. S. M. E. Boiler Code Committee and they are usually devoted to the administrative questions that arise in connection with the administration of boiler and pressure vessel legislation in the various states. The National Board also devotes a great deal of attention to the question of uniformity in the application of the rules recommended by the Boiler Code Committee.

Inasmuch as fusion welding methods of fabrication are coming into almost universal use in the plants of boiler and pressure vessel manufacturers, this representation has afforded an unusual opportunity to offer constructive advice to this organization leading to employment of inspection and testing practices as they are applied to welded construction. The attention that has been given to welding developments has undoubtedly fostered its use in the pressure vessel field as a fabricating method. In fact, remarkable advances have been observed during the past year in not only the development of the art but also the recognition of welding methods of fabrication by the various Code jurisdictions.

*Committee Appointments*

By authority of the Board of Directors the following standing and special committees have been appointed during the year:

Committee to Report on Plan for Preparation of Welding History.
Special Committee to Report on Selection Personnel for Second Welding Handbook Committee.
Welding Handbook Committee.
1940 Nominating Committee.
Judges of R. W. M. A. Contest.
Permanent Funds Committee.

*Education*

Although the Sections have asked for no assistance this past year in the preparation of lecture courses, Headquarters in its monthly News Letters has endeavored to stimulate interest in different activities. Attempt will be made to further arouse interest in this branch of Section Activities during the coming year.

*Public Relations*

The primary function of this Committee is to deal with state and federal legislative matters detrimental to welding which are brought to the attention of the Society. As in the past this Committee has rendered invaluable but unobtrusive service.

*Code of Principles of Conduct*

It is pleasing to report that it has been found unnecessary for this Committee to function during the past year.

*Admission to Membership*

No meetings of this Committee have been held as it was found feasible to conduct business by correspondence. Cases in doubt as to the applicant's eligibility to the class applied for were referred to the Committee. The Committee rendered its decisions on these cases and the applicants were accordingly informed.

*Death of Past President Lang*

The Society has suffered a severe loss during the past year in the death of Mr. Lang, who served as President of the Society during the administrative year 1937–38.

*H. O. Hill Named Director*

On recommendation of the Executive Committee, the Board of Directors names Mr. H. O. Hill as a member of the Board of Directors to replace Mr. L. S. Moisseiff who had been selected Second Vice-President of the Society. Mr. Hill's term ran from November 1939 to October 1940. He has been re-elected to this office and his new term of three years will commence in October 1940.

*Second Edition of the Welding Handbook*

The eagerness for information and a broader knowledge of welding has resulted in the Society having on file a large number of orders and requests for the Welding Handbook. The first edition of the book has been out of print for several months.

A second edition has been authorized, and for the past few months the new Editorial Committee has been at work in preparing a list of chapters and selecting the best talent for the preparation of these chapters. The new book will probably come out the latter part of 1941.

*Welding History*

Early in the year consideration was given the advisability of the A. W. S. undertaking the preparation of a Welding History. It was believed such a history is worth while and should be done while some of the pioneers in the field are still available. A Committee was appointed to investigate the available talent and to consider plans for carrying out the work. Because of the general conditions at the present time, it has been recommended that action on the preparation of the Welding History be delayed, although it was deemed desirable to encourage the collection of monographs or statements by individuals connected with the welding industry, relating to the history of welding.

*Resistance Welder Manufacturer's Association Prize Contest*

At the request of the R. W. M. A. the A. W. S. accepted sponsorship for the judging and awarding of cash prizes which have been offered in the R. W. M. A. Contest for Technical Papers on Resistance Welding Subjects, and a Committee of three was appointed to judge these prize papers in accordance with rules approved by both organizations. The report of this Committee will undoubtedly be rendered in time for presentation of the prizes at the coming Annual Meeting.

*Medal Awards*

The Board of Awards has selected the following candidates for the awards to be presented at the 1940 Annual Meeting:

Samuel Wylie Miller Memorial Medal for the year 1939—William Spraragen.
Lincoln Gold Medals—H. J. French and T. N. Armstrong, Jr.

*Employment Service*

For the benefit of the Society membership and welding industry a column in THE WELDING JOURNAL is devoted each month to Positions Vacant and Services Available. We are able to include only those coming to the attention of Headquarters. We shall be glad to have more of the members of the Society take advantage of this service.

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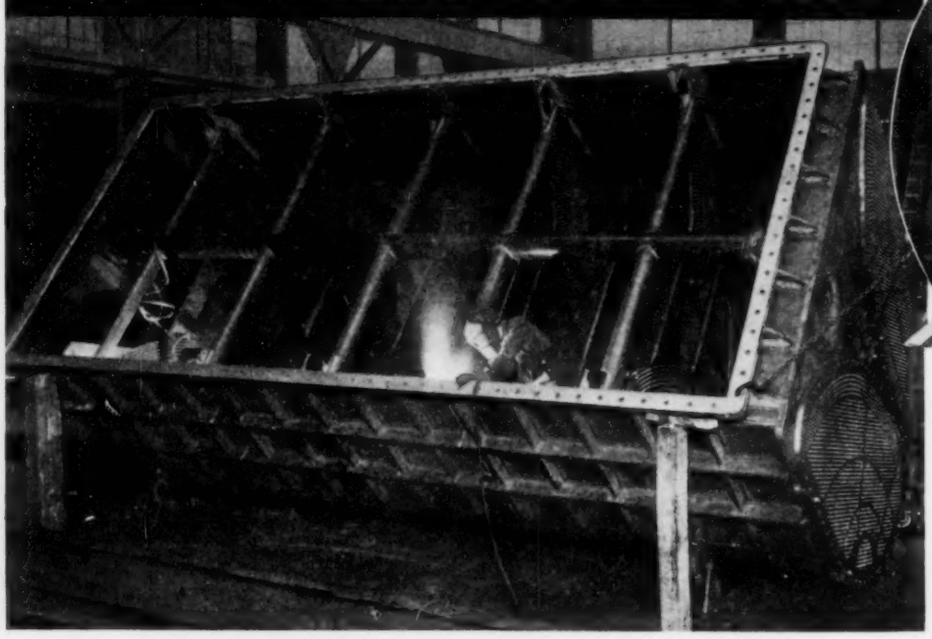
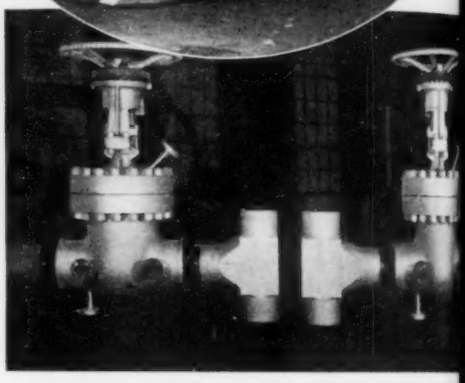


Murex-welded shell and turbine connector, 27,500 sq. ft. surface condenser, built by Ross Heater & Mfg. Co., Buffalo.

35 cu yd dipper built of Man-Ten steel and welded with Murex Carbon-Moly by Marion Steam Shovel Co., Marion, O.



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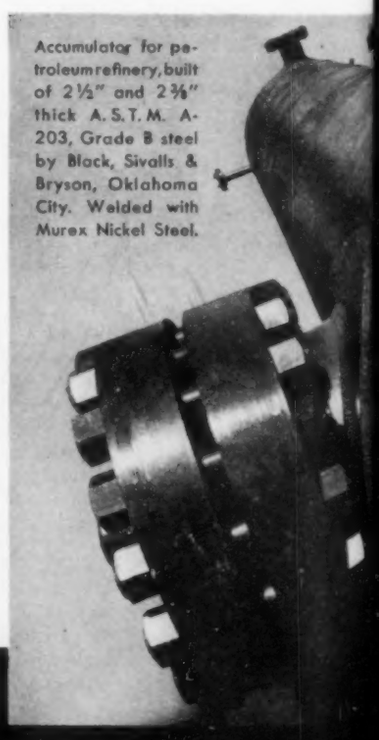

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